EXHIBIT 11

LIEBEL-FLARSHEIM COMPANY and MALLINCKRODT, INC., Plaintiffs-Appellants, v. MEDRAD, INC., Defendant-Cross Appellant.

06-1156, 06-1157

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

2007 U.S. App. LEXIS 6607

March 22, 2007, Decided

PRIOR HISTORY: [*1] Appealed from: United States District Court for the Southern District of Ohio. Chief Judge Sandra S. Beckwith. *Liebel-Flarsheim Co. v. Medrad Inc., 2005 U.S. Dist. LEXIS 25733 (S.D. Ohio, Oct. 28, 2005)*

DISPOSITION: AFFIRMED.

COUNSEL: J. Robert Chambers, Wood, Herron & Evans, L.L.P., of Cincinnati, Ohio, argued for plaintiffs-appellants. With him on the brief was Theodore R. Remaklus.

W. Thomas McGough, Jr., Reed Smith LLP, of Pittsburgh, Pennsylvania, argued for defendant-cross appellant. With him on the brief were Frederick H. Colen, Barry J. Coyne, and Kirsten R. Rydstrom. Of counsel on the brief was Gregory L. Bradley, Medrad Inc., of Indianola, Pennsylvania.

JUDGES: Before LOURIE, RADER, and BRYSON, Circuit Judges.

OPINION BY: LOURIE

OPINION: LOURIE, Circuit Judge.

Liebel-Flarsheim Company and Mallinckrodt Inc. (collectively "Liebel") appeal from the decision of the United States District Court for the Southern District of Ohio granting Medrad's motion for summary judgment that four of Liebel's patents are invalid under *35 U.S.C. §§ 112* and *102*. *Liebel-Flarsheim Co. v. Medrad, Inc., No. 01-CV-98-858, 2005 U.S. Dist. LEXIS 25733 (S.D. Ohio Oct. 28, 2005)*. Medrad cross-appeals from the decision of the district court granting Liebel's motion for summary judgment that [*2] Medrad infringed the asserted patents and that the inventorship designation on Liebel's patents is correct. Medrad also cross-appeals from the holding that the inequitable conduct counterclaim was moot in light of the district court's invalidity rulings. Because we conclude that Liebel's patents are invalid, the front-loading patents for lack of enablement and the syringe-sensing patents on anticipation, we affirm the district court's judgment of invalidity. As a result, the cross-appeals on infringement and inventorship need not be reached. We also affirm the court's decision that the inequitable conduct counterclaim is presently moot.

BACKGROUND

This is the second time this case has been on appeal in our court. The detailed facts of the case are presented in our previous opinion, and we present here only those facts relevant to this appeal. See *Liebel-Flarsheim Co. v. Medrad, Inc., 358 F.3d 898 (Fed. Cir. 2004)* ("Liebel I"). This appeal concerns asserted claims of four of Liebel's patents: claims 10, 11, 13, and 16-19 of *U.S. Patent 5,456,669*; claims 1, 8, 9, 11-13, 15, 16, 18, 22, 27, 28, 30-33, and 34-37 of *U.S. Patent 5,658,261*; claims 7, 8, 10, and 11 of [*3] *U.S. Patent 5,662,612*; and claims 1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, and 23 of *U.S. Patent 5,928,197*. The *'669* and *'261 patents* (hereinafter the "front-loading patents") share a common specification and are directed to a front-loading fluid injector with a replaceable syringe capable of withstanding high pressures for delivering a contrast agent to a patient. The *'612* and *'197 patents* (hereinafter the "sy-

ringe-sensing patents") also share a common specification and are directed to a computer-controlled injector wherein a motor advances and retracts a plunger located within the syringe.

With regard to the asserted claims of the front-loading patents, this appeal challenges the district court's holding of invalidity following our prior claim construction regarding a pressure jacket. Claim 10 of the *'669 patent* is representative of the asserted claims of the front-loading patents and reads as follows:

> A method of loading a tubular replacement syringe into a high pressure power injector for injecting fluid into an animal, the method comprising the steps of:
>
> > providing a power injector having:
> >
> > a syringe receiving opening with a generally circular [*4] periphery therein adapted to receive a rearward end of a syringe having a generally circular rim,
> > a ram and a motor linked to the ram and operable to reciprocate the ram along a segment of a line projecting through the opening; and providing a hollow tubular syringe that includes:
> > a cylindrical body having an axis, a generally circular rim, a rearward end and a closed forward end with a fluid discharge orifice therein, and
> > a plunger axially slidable in the body, the syringe body being structurally capable of withstanding, at least from the rim to the orifice, fluid at an operating pressure of at least 100 psi within the interior thereof;
>
> then:
>
> > inserting into the opening, by generally rearward axial movement of the syringe, the rearward end of the body;
> >
> > rotating the syringe in the opening a fraction of a turn to thereby lock the body around the rim to the injector around the periphery of the opening; and
> >
> > engaging the plunger with the ram;
>
> then:
>
> > energizing the motor and thereby driving the ram forward along the line and parallel to the axis to move the plunger axially forward at a programmed speed to inject the fluid at the operating pressure [*5] from within the syringe and through the orifice at a programmed rate into the animal.

'669 patent, col.15 ll.17-50. The claims in the originally-filed application n1 explicitly recited a pressure jacket in front of the syringe receiving opening. During the prosecution of the front-loading patents, Liebel removed all references in the claims to a pressure jacket. Medrad asserted, and the district court agreed, that during the prosecution of the front-loading patents, the applicants became aware of Medrad's jacketless injector system and then deleted all references to a pressure jacket in the asserted claims in order to encompass Medrad's injector within the scope of the claims. The examiner allowed the claims, and the claims as issued do not contain an explicit recitation of a pressure jacket.

> n1 In 1991, Liebel filed Application Serial No. 07/712,110, which issued as *U.S. Patent 5,300,031*. The claims of the *'031 patent* include a pressure jacket limitation. The *'669* and *'261 patents*, which do not recite a pressure jacket limitation, resulted from continuation applications, claiming priority from the '110 application.

Even though the claims do not expressly [*6] recite a pressure jacket, the district court initially construed the asserted claims of the front-loading patents as requiring a pressure jacket. Based on that construction, the district court granted summary judgment of noninfringement in favor of Medrad because Medrad's accused devices do not contain a pressure jacket.

In the first appeal to this court, we reversed the district court's claim construction and determined that the asserted claims of the front-loading patents do not require a pressure jacket. We first considered the language of the claims and observed that neither claim 10 of the *'669 patent* nor any of the other asserted claims expressly mentions a pressure jacket. We further rejected the district court's conclusion that the term "opening" in independent claim 10 of the *'669 patent* must be limited to an opening in a pressure jacket. We then considered the specification and determined that, although all the described embodiments include a pressure jacket, the disclosure did not clearly disavow embodiments lacking a pressure jacket. We also observed that the prosecution history indicates that the asserted claims purposefully did not include a pressure jacket limitation [*7] in order to cover devices that lacked a pressure jacket. In light of the intrinsic evidence, we declined to limit the claims to require a pressure jacket. Although Medrad argued that we should construe the claims narrowly to preserve their validity, we declined to do so, stating that the question of validity was a separate issue that could be addressed on remand. *Liebel I, 358 F.3d at 912.*

On remand and in light of our claim construction, the district court concluded that Medrad's devices did infringe the asserted claims of the front-loading patents, but that those claims were invalid for lack of compliance with the written description and enablement requirements of the statute. The district court reasoned that the claims were invalid for lack of written description because the specification does not describe a jacketless injector. The court noted that the written description of the invention is directed to the improvement of "loading and unloading a syringe given the constraints presented by the pressure jacket."

The district court also concluded that the asserted claims were invalid for lack of enablement after considering the specification and the factors set [*8] forth in *In re Wands, 858 F.2d 731 (Fed. Cir. 1988).* The court observed that a pressure jacket was necessary to "maintain the integrity of the syringe housing against pressures the syringe encounters during operation of the injector." The court further noted that the inventors themselves testified as to the importance of the pressure jacket around the syringe and that the experiments with and testing of jacketless systems were unsuccessful. The court also relied on testimony of Liebel's engineers that a jacketless system was not a mere design option and that one skilled in the art would not know how to make a jacketless system. The court further found that no prototypes of a jacketless injector had been made or described at the time of filing, and that the state of the art was such that a jacketless system with a disposable syringe would have been a "true innovation." Thus, the court concluded that Medrad had proffered clear and convincing evidence that the specification does not satisfy the written description and enablement requirements.

With respect to the syringe-sensing patents, this appeal challenges the holding of invalidity following our construction of the [*9] term "physical indicia" and its relationship to the properties of the syringe. Claim 7 of the *'612 patent* is representative of the asserted claims of the syringe-sensing patents and reads as follows:

> An injector of the type having a motor which advances and retracts a plunger located within a syringe toward and away from a nozzle located at a distal end of the syringe to inject fluid into or out of an animal subject, adapted for use with syringe assemblies which have differing capacities, comprising:
>
> a detector located proximate to a syringe installed on said injector for detecting a physical indicia [sic] on said syringe related to the capacity of said syringe, and generating an electrical signal representative of said physical indicia, and
> a control circuit which causes said motor to move and tracks the location of said motor while moving said motor, wherein said control circuit computes the location of a plunger within said syringe relative to an end of said syringe, by relating said electrical signal to the tracked location of said motor.

'612 patent, col.18 ll.36-52 (emphases added). The remaining asserted claims of the *'197* and *'612 patents* differ [*10] from representative claim 7 of the *'612 patent* in that some are directed to a method of controlling an injector (claims 4, 5, 10, 11, 16, 17, 22, and 23 of the *'197 patent* and claim 10 of the *'612 patent*), and some are dependent claims that recite the additional limitation of ceasing motion of the motor and plunger when the plunger or ram connected to the plunger has reached the end of the syringe (claims 2, 5, 8, 11, 14, 17, 20, and 23

of the *'197 patent* and claims 8 and 11 of the *'612 patent*). In addition, the asserted claims of the syringe-sensing patents recite physical indicia related to properties of the syringe other than the "capacity of said syringe" as recited in representative claim 7 of the *'612 patent*. Such properties include the distance of the plunger or ram coupled to the plunger from an end of the syringe (claims 1, 4, 13, and 16 of the *'197 patent*), the range of travel of an injector ram coupled to the plunger (claims 19 and 22 of the *'197 patent*), and the amount of fluid in the syringe (claims 7 and 10 of the *'197 patent*).

In its claim construction prior to our decision in Liebel I, the district court had considered the meaning of the term "physical indicia. [*11] " It disagreed with Medrad that the term should be limited to indicia representing the length of the extender. The court determined that the claim language was broader than Medrad's proposed construction because the claims recited syringe properties other than the length of the extender.

On appeal, in Liebel I, Medrad had argued that we should construe the term "physical indicia" to be limited to features that indicate the length of the extender. *Liebel I, 358 F.3d at 912*. After considering the language of the claims, the specification, and the prosecution history, we determined that the district court correctly concluded that the term "physical indicia" is not limited to indicia related to the length of an extender. *Id. at 914*. We again stated that we would not construe the claims narrowly because of invalidity concerns, and that the issue of invalidity could be addressed on remand. Id.

On remand and in light of our construction, the district court determined that Medrad's accused device did infringe the asserted claims of the syringe-sensing patents, but that those claims were invalid for failure to comply with the requirements of *§ 112* [*12] and because of anticipation by Medrad's *U.S. Patent 5,383,858*. With regard to written description, the district court stated that there was "nothing in the written description that describes an invention for detecting indicia (e.g., 'a tangible mark') on the syringe -- other than the limited, alternative reference to physical indicia relating to the length of the extender." The district court noted that the preferred embodiment "teaches that it is the injector's face plate, which is removable and interchangeable, that is 'detected' by a sensor, which in turn tells the circuit board the size of the syringe installed." The court also observed that the written description and enablement requirements often rise and fall together and determined that the asserted claims of the front-loading patents "are of a far greater scope than [Liebel's] specification of what it invented or possessed when it filed its application." The court concluded that the specification failed to fulfill both the written description and enablement requirements set forth in *§ 112*, P 1.

With regard to anticipation, the court found that even if it had concluded that Liebel's patents were not invalid under *§ 112*, [*13] the asserted claims of the syringe-sensing patents were anticipated by the prior art *'858 patent*. The court found that the *'858 patent* clearly describes an indicator mechanism for injecting fluid from a syringe into a patient, and that mechanism includes an injector controller and a sensor. The court further determined that the *'858 patent* discloses "physical indicia" by describing the use of a bar code or another readable device on the syringe that stores information about the syringe and that can be read by a sensor. The court determined that the only difference between the asserted claims of the syringe-sensing patents and the invention disclosed in the *'858 patent* was the description of the types of indicia detected. For example, the *'858 patent* describes that the bar code on the syringe can include information relating to the "dimensions" of the syringe, whereas the asserted claims recite the "capacity" of the syringe. The court found that these were "semantic differences" that did not affect its conclusion of anticipation. Hence, the court concluded that the *'858 patent* anticipates the syringe-sensing patents.

In a separate order, the district court considered whether the inventorship [*14] designated on the patents was correct, and granted Liebel's motion for partial summary judgment that it was correct. The court determined that the alleged omitted inventor, Kelly, did not contribute to the conception of the design and thus was not properly a co-inventor. The court found that the evidence established that Kelly only attended "brainstorming" sessions, but that there was no clear and convincing evidence of his being an inventor.

The court further determined, after resolving the invalidity motions, that Medrad's inequitable conduct claim was moot in light of its invalidity rulings.

Liebel timely appealed, and Medrad cross-appealed. We have jurisdiction pursuant to *28 U.S.C. § 1295(a)(1)*.

DISCUSSION

We review the district court's grant of summary judgment de novo, reapplying the standard applicable at the district court. See *Rodime PLC v. Seagate Tech., Inc., 174 F.3d 1294, 1301 (Fed. Cir. 1999)*. Summary judgment is appropriate "if the pleadings, depositions, answers to interrogatories, and admission on file, together with the affidavits, if any, show that there is no genuine issue as to any material fact and that the moving [*15] party is entitled to judgment as a matter of law." *Fed. R. Civ. P. 56(c)*. In addition, in deciding a motion for summary judgment, "[t]he evidence of the nonmovant is to be believed, and all justifiable inferences are to be drawn in his favor." *Anderson v. Liberty Lobby, Inc., 477 U.S. 242, 255, 106 S. Ct. 2505, 91 L. Ed. 2d 202 (1986).*

Whether a claim satisfies the enablement requirement of *35 U.S.C. § 112*, P 1 is a question of law. *Invitrogen Corp. v. Clontech Labs. Inc., 429 F.3d 1052, 1070 (Fed. Cir. 2005)*. Anticipation is a question of fact, but validity is a question of law. *Atofina v. Great Lakes Chem. Corp., 441 F.3d 991, 995 (Fed. Cir. 2006)*. Because a patent is presumed to be valid, the evidentiary burden to show facts supporting a conclusion of invalidity is one of clear and convincing evidence. *AK Steel Corp. v. Sollac & Ugine, 344 F.3d 1234, 1238-39 (Fed. Cir. 2003)*.

A. The Front-Loading *'669* and *'261 Patents*

On appeal, Liebel argues that the court erred in determining that the asserted claims of the front-loading patents are invalid for lack of [*16] written description and enablement. With regard to enablement, Liebel contends that the court erroneously considered whether an injector without a pressure jacket was enabled, rather than limiting its inquiry to whether an injector with a pressure jacket was enabled, as it clearly was. Liebel points out that the asserted claims do not recite or require the absence of a pressure jacket and the court improperly focused on such an embodiment. Because it is undisputed that Liebel provided an enabling disclosure of what it calls its preferred embodiment, viz., an injector with a pressure jacket, Liebel asserts that the court should have held that the disclosure was enabling for the full scope of the claims. Liebel further asserts that the court erred in concluding, after considering the Wands factors, that undue experimentation would be required to practice the claimed invention without a pressure jacket. According to Liebel, the testimony that the court relied upon only showed that additional work, not undue experimentation, was required to develop an injector without a pressure jacket. Liebel also ascribes error to the court's consideration of various other pieces of testimony [*17] as support for its determination that producing the invention without a pressure jacket would require undue experimentation.

Medrad responds that the district court correctly determined that, under our claim construction, the asserted claims are invalid for lack of enablement. Medrad argues that the court was correct in determining that the full scope of the invention, including the injector without a pressure jacket, is not enabled. According to Medrad, although every embodiment of a claim does not need to be disclosed in the specification, the disclosure must teach the full range of embodiments in order for the claims to be enabled, and here the disclosure does not teach an injector without a pressure jacket. According to Medrad, consideration of the Wands factors also supports a determination that the asserted claims are not enabled. Medrad observes that Liebel's own inventors admitted that they could not produce a successful pressure-jacketless system and that that was compelling evidence of lack of enablement. Medrad also cites other testimony that supports a finding of undue experimentation.

We agree with Medrad that the district court correctly determined that the asserted [*18] claims of the front-loading patents are invalid for lack of enablement. The enablement requirement is set forth in *35 U.S.C. § 112*, P 1 and provides in pertinent part that the specification shall describe "the manner and process of making and using [the invention], in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the [invention]." We have stated that the "enablement requirement is satisfied when one skilled in the art, after reading the specification, could practice the claimed invention without undue experimentation." *AK Steel, 344 F.3d at 1244*; see also *Wands, 858 F.2d at 736-37*.

We have previously construed the claims of the front-loading patents such that they are not limited to an injector with a pressure jacket, and therefore the full scope of the claimed inventions includes injectors with and without a pressure jacket. That full scope must be enabled, and the district court was correct that it was not enabled.

Turning first to consideration of the specification, we find that nowhere does the [*19] specification describe an injector with a disposable syringe without a pressure jacket. In fact, the specification teaches away from such an invention. In the "Background of the Invention," the specification describes general injectors and explains that during the injection phase, a plunger is driven forward and pressure develops in the syringe, ranging from 25 psi to over 1000 psi. Without a pressure jacket, syringes that are able to withstand such high pressures are "expensive and therefore impractical where the syringes are to be disposable. Accordingly, many such injectors . . . have been provided with pressure jackets fixed to the injector units and into which the syringes are inserted." *'669 patent*, col.1 ll.23-31. The specification thus teaches away from a disposable syringe without a pressure jacket by stating that such syringes are "impractical." As we have held previously, where the specification teaches against a purported aspect of an invention, such a teaching "is itself evidence that at least a significant amount of experimentation would have been necessary to practice the claimed invention." *AK Steel, 344 F.3d at 1244*. Moreover, consideration of the [*20] remainder of the specification reveals that there is no guidance or suggestion of how to make or use a disposable syringe for high pressure use without a pressure jacket. All the figures in the patents depict a pressure jacket and all discussion of them refers to the pressure jacket.

Furthermore, consideration of the testimonial evidence presented supports a conclusion that no genuine issue of material fact exists as to whether undue experimentation would have been required to make and use the injector without a pressure jacket. The inventors admitted that they tried unsuccessfully to produce a pressure-jacketless system and that producing such a system would have required more experimentation and testing. The inventors decided not to pursue such a system because it was "too risky." The district court relied on various statements in the record by the inventors that testing of a syringe without a pressure jacket proved unsuccessful and that the inventors were not aware of any other similar testing being conducted at that time. Moreover, there was no indication of any prototype of a pressure-jacketless injector having been made.

Liebel argues that language in *Spectra-Physics, Inc. v. Coherent, Inc., 827 F.2d 1524 (Fed. Cir. 1987),* [*21] that states that if an invention pertains to an art where the results are predictable, e.g., in the mechanical arts, then disclosure of a single embodiment can enable a broad claim, supports its position. Liebel asserts that because the specification enables one mode of making and using the invention in its preferred embodiment, viz., an injector with a pressure jacket, the enablement requirement is satisfied and the inquiry should end there. See *Engel Indus., Inc. v. Lockformer Co., 946 F.2d 1528 (Fed. Cir. 1991).*

Liebel's reliance on *Spectra-Physics* is misplaced. In that case, the specification disclosed different "attachment means" for making the claimed invention such as moly-manganese brazing and pulse-soldering, but failed to disclose the best attachment means known to the inventors. We held that the asserted claims of the patent were invalid for failure to comply with the best mode requirement of *§ 112*, even though the specification enabled the practice of the claims. We did note that the specifications of other patents identified TiCuSil brazing as a suitable alternative attachment technique and thus that the asserted patent's failure to mention [*22] TiCuSil brazing as an attachment means was "not fatal to enablement under *§ 112*." *Spectra-Physics, 827 F.2d at 1533*. Indeed, in that case, disclosure of one attachment means permitted one skilled in the art to make and use the invention as broadly as it was claimed, which included other attachment means known to one of ordinary skill in the art. In contrast, in this case, disclosure of an injector system with a pressure jacket does not permit one skilled in the art to make and use the invention as broadly as it was claimed, including without a pressure jacket.

The facts of this case are, in fact, more analogous to *AK Steel* than to *Spectra-Physics*. In AK Steel, the patentee argued, as it does here, that the patent disclosed several embodiments within the properly construed claim, and that the specification need not teach the full claimed scope in order for the claims to be enabled. *344 F.3d at 1243*. The claims in AK Steel read on steel strips containing either a Type 1 or a Type 2 aluminum coating. The specification clearly described only Type 2 aluminum coating. We stated, however, that "as part of the quid pro quo of the patent bargain, [*23] the applicant's specification must enable one of ordinary skill in the art to practice the full scope of the claimed invention." *Id. at 1244* (latter emphasis added). We explained that the specification need not necessarily describe how to make and use every embodiment of the invention "because the artisan's knowledge of the prior art and routine experimentation can often fill in the gaps." Id. However, because the full scope of the claims included both Type 1 and Type 2 aluminum coating, the relevant inquiry became whether one skilled in the art would have been able to make and use a steel strip containing a Type 1 aluminum coating at the time of the patent's effective filing date. Id. We held that the specification taught against using a Type 1 aluminum coating, and therefore that the claims were invalid for lack of enablement.

Similarly, in this case, the asserted claims read on, and the full scope of the claimed invention includes, an injector system with and without a pressure jacket. There must be "reasonable enablement of the scope of the range" which, in this case, includes both injector systems with and without a pressure jacket. Id.

The specification's [*24] reference that teaches away from an injector system with a disposable syringe without a pressure jacket, combined with the testimonial evidence that such a system could not have been produced at the time of filing, supports the district court's conclusion that the specification fails to fulfill the enablement requirement of *§ 112*. Because we are resolving this issue on the enablement ground, we do not need to consider the written description holding of invalidity.

The irony of this situation is that Liebel successfully pressed to have its claims include a jacketless system, but, having won that battle, it then had to show that such a claim was fully enabled, a challenge it could not meet. The motto, "beware of what one asks for," might be applicable here.

B. The Syringe-Sensing *'612* and *'197 Patents*

On appeal, Liebel argues that Medrad failed to provide clear and convincing evidence that the *'858 patent* anticipates the asserted claims of the syringe-sensing patents. In particular, Liebel asserts that the *'858 patent* does not disclose a control circuit that computes the location of the plunger within the syringe, stops the motor

and plunger, or determines that the plunger [*25] is at the end of the syringe, as required by the claims.

Medrad responds that the district court correctly decided that the *'858 patent* anticipates the asserted claims of the syringe-sensing patents. Medrad asserts that the the *'858 patent* expressly discloses an injector control that controls a motor and plunger by computing the location of the plunger. Medrad also asserts that the district court held that measuring actual plunger movement is accomplished by "long-established potentiometer technology," and that the *'858 patent* incorporates two patents that discuss measuring plunger movement. Medrad finally contends that the *'858 patent* discloses detecting the same physical indicia as the syringe-sensing patents.

We agree with Medrad that the district court correctly determined that there is no genuine issue of material fact that the *'858 patent* anticipates n2 the asserted claims of the syringe-sensing patents. A determination that a patent is invalid as anticipated under *35 U.S.C. § 102* requires that a prior art reference disclose every limitation of the claimed invention, either explicitly or inherently. *Telemac Cellular Corp. v. Topp Telecom, Inc., 247 F.3d 1316, 1327 (Fed. Cir. 2001).* [*26] The prior art reference in this case is Medrad's *'858 patent*, which was cited to the PTO during the prosecution of the syringe-sensing patents. Although the burden of showing invalidity is "especially difficult" when the prior art reference was before the examiner during prosecution, we find that Medrad has met that burden here. See *Glaxo Group Ltd. v. Apotex, Inc., 376 F.3d 1339, 1348 (Fed. Cir. 2004).*

> n2 Because we determine that the asserted claims of the syringe-sensing patents are invalid by reason of anticipation by the *'858 patent*, we need not address written description or enablement issues, which were the other grounds on which the district court found the syringe-sensing patents to be invalid.

Liebel first argues that the *'858 patent* fails to disclose the closed control circuit that computes the location of a plunger, as required by claim 7 of the *'612 patent*. We disagree. There is no genuine issue of material fact as to what the *'858 patent* discloses. The *'858 patent* discloses a syringe that is rotatably mountable on a front wall of an injector housing with an interference fit. Although that patent expressly mentions an injector controller, [*27] it does not discuss the details of how the controller interacts with the motor and plunger. However, the *'858 patent* incorporates by reference n3 *U.S. Patent 4,006,736*, assigned to Medrad, which clearly does discuss the details of the control circuit and its interaction with the plunger. The *'736 patent* discloses a system for injecting fluid into a patient and it is replete with discussion of the control unit of that system operating the motor and tracking the plunger movement. For example, the patent expressly states that "as the motor drives the plunger, the potentiometer tracks it, so that the rate of movement and position may be derived." *'736 patent*, col.20 ll.21-24 (reference characters omitted). The *'736 patent* further states that "the volume circuit monitors the position of plunger after an injection begins to determine how much volume of contrast media has been delivered. And when the plunger has delivered the set volume, the volume circuit sends a signal to the time circuit to stop injecting." *'736 patent*, col.19 ll.32-37 (reference characters omitted). The *'858 patent*, which incorporates by reference the *'736 patent*, therefore discloses a claimed control circuit that computes [*28] the location of a plunger. In addition, the limitation recited in some of the dependent claims of the syringe-sensing patents -- using the control circuit to stop movement of the motor and plunger when the plunger is at the end of the syringe -- is similarly disclosed in the *'736 patent* in the discussion pertaining to moving and retracting the plunger.

> n3 We have stated that "material not explicitly contained in the single, prior art document may still be considered for purposes of anticipation if that material is incorporated by reference into the document." *Advanced Display Sys., Inc. v. Kent State Univ., 212 F.3d 1272, 1282 (Fed. Cir. 2000).* We have further explained that material incorporated by reference "is effectively part of the host document as if it were explicitly contained therein." Id.

Liebel next asserts that the *'858 patent* fails to disclose physical indicia related to various parameters or properties of the syringe. We disagree again. In our claim construction, we determined that the term "physical indicia," as Liebel has argued, is not limited to indicia related to the length of the extender. Thus, the full scope of the claims [*29] includes the detection of physical indicia other than detection of the length of the extender. Those physical indicia recited in the claims are: the capacity of the syringe, the distance of the plunger from an end of the syringe, the amount of fluid in the syringe, and the end of the travel position of an injector ram coupled to the plunger.

The *'858 patent* discloses using an encoding device, such as a bar code, located on the syringe, and a sensor, located on the injector, for reading the encoded device and forwarding signals to the injector controller to modify the injector apparatus accordingly. *'858 patent*, col.6 ll.31-45. The *'858 patent* also states that as an alternative

to the encoding device being a bar code with spaced bars, the encoding device can include raised surfaces corresponding to the spaced bars that would be read by an injector sensor, or can include mechanically readable devices such as a slot, hold, or projection on the syringe or plunger that would send information concerning the type of syringe used to the circuits of the injector. *'858 patent*, col.6 ll.51-65. The *'858 patent* provides the following examples of the information that can be included in the encoding [*30] device: "dimensions of the syringe, content of the syringe in the case of a pre-filled syringe, manufacturing information such as lot numbers, dates and tool cavity number, recommended contrast media flow rates and pressures, and loading/injection sequences." *'858 patent* col.6 ll.45-51. Thus, the *'858 patent* clearly discloses the detection of various parameters of the syringe through the use of a bar code or other marks on the syringe.

Liebel asserts that "dimensions of the syringe" are not the same as "capacity of the syringe," as recited in the asserted claims. As the district court observed, detecting dimensions of the syringe permits calculation of capacity using a basic volumetric formula. Moreover, the *'858 patent* expressly lists as an example of the type of information that can be included in the bar code the "content of the syringe," which can encompass the capacity of the syringe as well as the amount of fluid in the syringe. The *'858 patent* also states that the encoding device can include the "loading/injection sequences," which can encompass information related to the initial position of the plunger. Moreover, although the *'858 patent* only provides a few examples of the [*31] types of information that can be stored in the encoding device, the list is not exclusive and may include other information logically related to the "dimensions" of the syringe or the "content" of the syringe, such as the initial plunger position. Thus, there is no genuine issue of material fact that the *'858 patent*, including the disclosure of the *'736 patent* that is incorporated by reference, clearly discloses the limitations of the asserted claims of the syringe-sensing patents. The district court therefore did not err in concluding that the syringe-sensing patents are invalid for anticipation as a matter of law.

Liebel argued for a broad construction of the term "physical indicia" and in fact broadened its claims during prosecution to recite physical indicia other than those indicating the length of an extender. Once again, Liebel argued for a broad meaning, and succeeded, but suffers a Pyrrhic victory.

C. Cross-Appeals

Because we affirm the district court's conclusion that the asserted claims of the patents at issue are invalid, we need not reach Medrad's cross-appealed issues concerning infringement and inventorship, the latter actually being an alternative ground [*32] for a holding of invalidity, not a proper basis for a cross-appeal. n4

n4 Medrad concedes that the arguments made on infringement provide alternate bases to find in its favor and that the arguments need only be addressed if we were to reverse on the issue of validity. Reply Br. n.1

D. Inequitable Conduct

Medrad finally argues that the district court should not have dismissed as moot its counterclaim asserting inequitable conduct. Medrad asserts that that counterclaim is independent and distinct from an invalidity claim, and it may be the basis for two additional remedies: a determination that the entire patent is unenforceable and an award of attorney fees under *35 U.S.C. § 285*.

We agree with the district court that the inequitable conduct counterclaim is moot. With regard to the argument that an inequitable conduct determination may render the entire patent unenforceable, Medrad admitted during oral arguments that such relief is not meaningful to Medrad at this time. The only other additional relief that may be available to Medrad by an inequitable conduct determination is attorney fees under *35 U.S.C. § 285* [*33] . Medrad admitted during oral arguments that, although it plans to predicate an attorney fee application on inequitable conduct, it has not filed that application yet. We therefore affirm the decision that the inequitable conduct counterclaim is presently moot.

CONCLUSION

Because the district court correctly granted summary judgment that Liebel's patents are invalid, we affirm the conclusion that all the asserted claims are invalid, the front-loading patents on enablement and the syringe-sensing patents on anticipation grounds. Because we find no error in the district court's holding that the inequitable conduct counterclaim is moot, we affirm that decision as well.

AFFIRMED

EXHIBIT 12

UNITED STATES DISTRICT COURT
DISTRICT OF DELAWARE

BRIDGESTONE SPORTS CO., LTD., and BRIDGESTONE GOLF, INC., Plaintiffs, v. ACUSHNET COMPANY, Defendant.	Case No. 05-CA-132 (JJF) **INVALIDITY EXPERT REPORT OF DR. DAVID FELKER**
ACUSHNET COMPANY, Counterclaimant, v. BRIDGESTONE SPORTS CO., LTD., and BRIDGESTONE GOLF, INC., Counterdefendant.	

center and surface); U.S. Patent No. 5,711,723 (Ex. 36) (1995 application, showing a hardness gradient of not more than 4); and U.S. Patent No. 5,730,663 (Ex. 37) (1995 application, showing the hardness in 5mm increments between the core center and surface).

Still other patents show a gradient of greater than 22 degrees before the earliest priority date of the'791 patent (2000). Bridgestone's own U.S. Patent No. 5,830,085 (Ex. 38), for example, showed the use of a gradient of 5 to 25 degrees in a three-piece golf ball in 1998. United States Patent No. 6,390,935 (Ex. 39), filed in 1999, taught a gradient of 8 to 25 degrees. And U.S. Patent No. 6,386,993 (Ex. 40), also filed in 1999, claimed a gradient of 20 to 40 degrees.

3. Hardness Gradient in the Core Manufacturing Process

Solid golf ball cores are manufactured through a curing process. During the curing of a golf ball core, raw polybutadiene is mixed with, among other things, a crosslinking agent or catalyst and heated in a mold. The use of peroxide catalysts, such as dicumyl peroxide, is common in the golf ball art. As the mold is heated, the peroxide breaks down, forming free radicals, which then cause the strands of polybutadiene to form bonds, or "cross-link," with each other. As the temperature increases and the curing time increases, the crosslinking increases. Crosslinking increases the hardness of rubber.

During the core manufacturing process, the rubber is heated by conduction from the hot metal mold. Heat is transferred from the mold to the surface of the cores, and then is conducted inwards. Because polybutadiene has a low thermal conductivity, the surface of the core heats up appreciably faster than the center. Therefore, there is a pronounced temperature difference in the core, with the outside of the core initially being much hotter than the center.

Conventional core molding processes are usually stopped before the core reaches complete thermal equilibrium. Consequently, the outer portions are heated to temperatures where peroxide decomposition and rubber crosslinking occurs for a longer time than the inner

US005830085A

United States Patent [19]

Higuchi et al.

[11] Patent Number: 5,830,085

[45] Date of Patent: Nov. 3, 1998

[54] **THREE-PIECE SOLID GOLF BALL**

[75] Inventors: **Hiroshi Higuchi; Hisashi Yamagishi; Yasushi Ichikawa**, all of Chichibu, Japan

[73] Assignee: **Bridgestone Sports Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **821,438**

[22] Filed: **Mar. 21, 1997**

[30] **Foreign Application Priority Data**

Mar. 29, 1996	[JP]	Japan	8-104307
Jul. 18, 1996	[JP]	Japan	8-207869

[51] **Int. Cl.**[6] **A63B 37/06**

[52] **U.S. Cl.** 473/373; 473/374; 473/378

[58] **Field of Search** 473/373, 374, 473/378

[56] **References Cited**

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Primary Examiner—George J. Marlo

Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas, PLLC

[57] **ABSTRACT**

The invention provides a three-piece solid golf ball having improved flight performance, durability, soft pleasant hitting feel, and controllability. To this end, in a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover, the solid core, intermediate layer, and cover each have a hardness as measured by a JIS-C scale hardness meter wherein the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 5 to 25 degrees, the intermediate layer hardness is higher than the core surface hardness by less than 10 degrees, and the cover hardness is higher than the intermediate layer hardness.

13 Claims, 1 Drawing Sheet

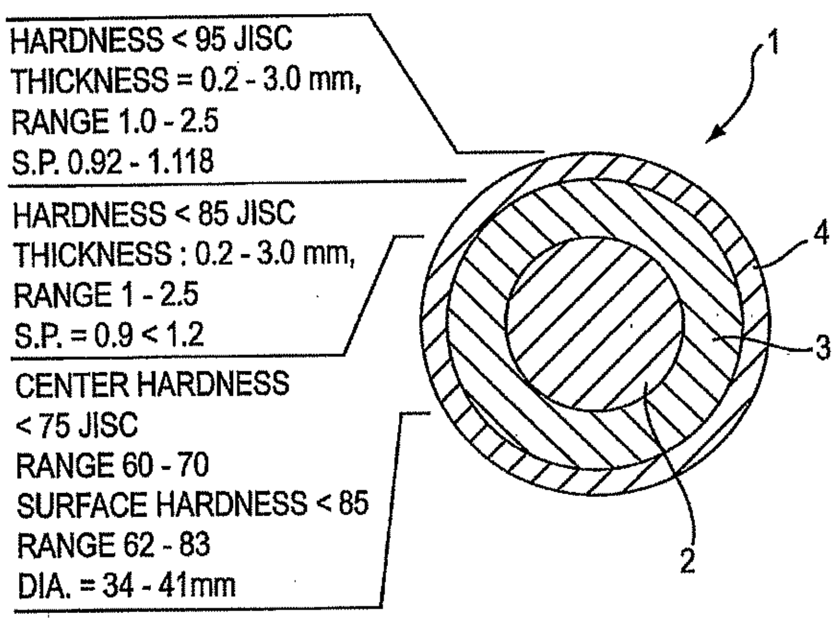
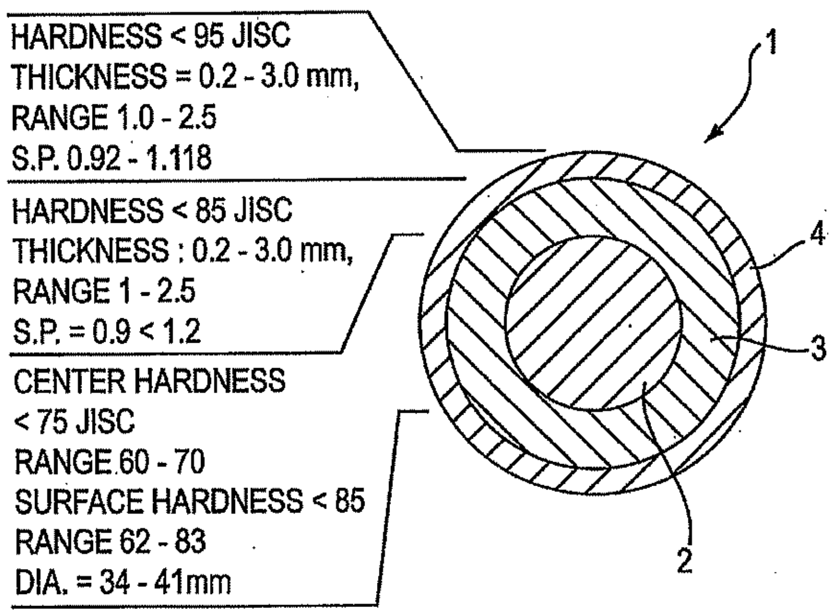


FIG. 1


HARDNESS < 95 JISC
THICKNESS = 0.2 - 3.0 mm,
RANGE 1.0 - 2.5
S.P. 0.92 - 1.118
HARDNESS < 85 JISC
THICKNESS : 0.2 - 3.0 mm,
RANGE 1 - 2.5
S.P. = 0.9 < 1.2
CENTER HARDNESS
< 75 JISC
RANGE 60 - 70
SURFACE HARDNESS < 85
RANGE 62 - 83
DIA. = 34 - 41mm
1
4
3
2

THREE-PIECE SOLID GOLF BALL

This application stems from and claims priority from the provisional application Ser. No. 60/025,418 filed Sep. 4, 1996.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover more particularly it relates to a three-piece solid golf ball which is imparted excellent flight performance, durability, pleasant hitting feel, and controllability and hence, all-around performance by optimizing the hardness distribution of the core and the overall hardness distribution of the ball including the core, intermediate layer, and cover.

2. Prior Art

In the past, golf balls of various structures have been on the market. Among others, two-piece solid golf balls having a rubber base core enclosed with a cover of ionomer resin or the like and thread-wound golf balls comprising a wound core having thread rubber wound around a solid or liquid center and a cover enclosing the core share the majority of the market.

Most amateur golfers are fond of two-piece solid golf balls which have excellent flying performance and durability although these balls have the disadvantages of a very hard feel on hitting and low control due to quick separation from the club head on hitting. For this reason, many professional golfers and skilled amateur golfers prefer wound golf balls to two-piece solid golf balls. The wound golf balls are superior in feeling and control, but inferior in carry and durability to the two-piece solid golf balls.

Under the present situation that two-piece solid golf balls and wound golf balls have contradictory characteristics as mentioned above, players make a choice of golf balls depending on their own skill and taste.

In order to develop solid golf balls having a feel approximate to the wound golf balls, various two-piece solid golf balls of the soft type have been proposed. To obtain such two-piece solid golf balls of the soft type, soft cores are used. Softening the core can reduce restitution, deteriorate flight performance, and substantially lower durability, resulting in two-piece solid golf balls which not only fail to possess their characteristic excellent flight performance and durability, but also lose actual playability. More specifically, the structure of conventional two-piece solid golf balls is decided depending on which is considered important among four factors, softness, restitution, spin and durability. An attempt to improve any one factor inevitably leads to lowering of the remaining factors.

Also, as a matter of course, controllability is needed on full shots with woods such as a driver and long irons. If a soft cover is used as a result of considering too much the purpose of improving spin properties upon control shots such as approach shots with a short iron, hitting the ball with a driver, which falls within an increased deformation region, will impart too much spin so that the ball may fly too high, resulting in a rather reduced flight distance. On the other hand, if the spin rate is too low, there arises a problem that the ball on the descending course will prematurely drop, adversely affecting the ultimate flight distance too. As a consequence, an appropriate spin rate is still necessary upon hitting with a driver.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a golf ball which can satisfy improved flight performance, durability, pleasant hitting feel, and controllability at the same time by optimizing the hardness distribution of the core and the overall hardness distribution of the ball including the core, intermediate layer, and cover.

Making extensive investigations on a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover for achieving the above object, we have found that by optimizing the hardness distribution of the core such that the core surface hardness is higher than the core center hardness, adjusting the intermediate layer hardness higher than the core surface hardness, and adjusting the cover hardness higher than the intermediate layer hardness, there is obtained a solid golf ball having an optimum hardness distribution to accomplish all-around performance in that the ball is improved in flight performance, durability, and controllability.

More specifically, we have found that the following advantages are obtained in a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover When the solid core, intermediate layer, and cover each have a hardness as measured by a JIS-C scale hardness meter, the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 5 to 25 degrees, the intermediate layer hardness is higher than the core surface hardness by less than 10 degrees, and the cover hardness is higher than the intermediate layer hardness. Then first a core having an optimum hardness distribution is formed. With respect to ball deformation upon impact, the core surface formed harder than the core center is effective for preventing excessive deformation and efficiently converting distortion energy into reaction energy. Then the flying distance is increased and a soft pleasant hitting feel is obtainable from the soft core center. Additionally, second by sequentially enclosing the core formed soft with a harder intermediate layer and a cover harder than the intermediate layer, the ball as a whole is given an optimum hardness distribution. There is obtained a golf ball which minimizes the energy loss caused by excessive deformation upon impact and has efficient restitution. Moreover, in the three-piece solid golf ball having the above-defined hardness distribution, thirdly if the intermediate layer and the cover are formed mainly of a thermoplastic resin containing 10 to 100% by weight of an ionomer resin, the intermediate layer can be firmly joined to the cover, and this firm joint combined with the cover formed hard is effective for improving durability.

We have found that owing to the above three advantages accomplished by setting the hardness distribution of a three-piece solid golf ball as defined above, there is obtained a golf ball which receives an optimized spin rate upon full shots with a driver or the like so that the flying distance is outstandingly increased and which is improved in both durability and hitting feel. The present invention is predicated on these findings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of a three-piece solid golf ball according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Now the present invention is described in further detail. Referring to FIG. 1, a three-piece solid golf ball 1 according

to the invention is illustrated comprising a solid core 2 having an optimized hardness distribution, an intermediate layer 3 harder than the surface of the core 2, and a cover 4 harder than the intermediate layer 3.

In the golf ball 1 of the invention, the hardness distribution of the solid core 2 is optimized. More particularly, the core 2 is formed to have a center hardness of up to 75 degrees, preferably 50 to 70 degrees, more preferably 51 to 68 degrees as measured by a JIS-C scale hardness meter. (The hardness is referred to as JIS-C hardness, hereinafter.) The core 2 is also formed to have a surface hardness of up to 85 degrees, preferably 60 to 85 degrees, more preferably 62 to 83 degrees. If the center hardness exceeds 75 degrees and the surface hardness exceeds 85 degrees, the hitting feel becomes hard, contradicting the object of the invention. If the core is too soft, on the other hand, a greater deformation occurs upon impact and the flying distance and durability are reduced due to an energy loss associated therewith.

The core is formed herein such that the surface hardness is higher than the center hardness by 5 to 25 degrees, preferably 7 to 22 degrees. With a hardness difference of less than 5 degrees, the core surface hardness is approximately equal to the core center hardness, which means that the hardness distribution is nil and flat, resulting in a hard hitting feel. For a hardness difference of more than 25 degrees, the core center hardness must be too low, failing to provide sufficient restitution. The hardness distribution establishing such a hardness difference between the surface and the center of the core ensures that the core surface formed harder than the core center is effective for preventing excessive deformation of the core and efficiently converting distortion energy into reaction energy when the ball is deformed upon impact. Additionally, a pleasant feeling is obtainable from the core center softer than the core surface.

The hardness distribution of the solid core is not limited insofar as the core is formed such that the core surface is harder than the core center by 5 to 25 degrees. It is preferable from the standpoint of efficient energy transfer that the core is formed such that the core becomes gradually softer from its surface inward toward its center.

The solid core preferably has a diameter of 34 to 41 mm, especially 34 to 39 mm. No particular limit is imposed on the overall hardness, weight and specific gravity of the core and they are suitably adjusted insofar as the objects of the invention are attainable. Usually, the core has an overall hardness corresponding to a distortion of 2.3 to 5.5 mm, especially 2.5 to 4.8 mm under a load of 100 kg applied the core has a weight of 25 to 42 grams, especially 27 to 41 grams.

In the practice of the invention, no particular limit is imposed on the core-forming composition from which the solid core is formed. The solid core may be formed using a base rubber, a crosslinking agent, a co-crosslinking agent, and an inert filler as used in the formation of conventional solid cores. The base rubber used herein may be natural rubber and/or synthetic rubber conventionally used in solid golf balls although 1,4-cis-polybutadiene having at least 40% of cis-structure is especially preferred in the invention. The polybutadiene may be blended with a suitable amount of natural rubber, polyisoprene rubber, styrene-butadiene rubber or the like if desired. The crosslinking agent includes organic peroxides such as dicumyl peroxide, di-t-butyl peroxide, and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, with a blend of dicumyl peroxide and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane being preferred. In order to form a solid core so as to have the above-defined hardness distribution, it is preferable to use a blend of dicumyl peroxide and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane as the crosslinking agent and the step of vulcanizing at 160° C. for 20 minutes. Also the difference in hardness between the core center and the core surface can be changed by suitably changing the vulcanizing temperature and time.

The co-crosslinking agent used herein is not critical. Examples include metal salts of unsaturated fatty acids, inter alia, zinc and magnesium salts of unsaturated fatty acids having 3 to 8 carbon atoms (e.g., acrylic acid and methacrylic acid), with zinc acrylate being especially preferred. It is noted that the amount of the crosslinking agent blended is suitably determined although it is usually about 7 to 45 parts by weight per 100 parts by weight of the base rubber. Examples of the inert filler include zinc oxide, barium sulfate, silica, calcium carbonate, and zinc carbonate, with zinc oxide and barium sulfate being often used. The amount of the filler blended is usually up to 40 parts by weight per 100 parts by weight of the base rubber although the amount largely varies with the specific gravity of the core and cover, the standard weight of the ball, and other factors and is not critical. In the practice of the invention, the overall hardness and weight of the core can be adjusted to optimum values by properly adjusting the amounts of the crosslinking agent and filler (typically zinc oxide and barium sulfate) blended.

The core-forming composition obtained by blending the above-mentioned components is generally milled in a conventional mixer such as a Banbury mixer and roll mill, compression or injection molded in a core mold, and then heat cured under the above-mentioned temperature condition, whereby a solid core having an optimum hardness distribution is obtainable.

The intermediate layer 3 enclosing the core 2 is formed to a JIS-C hardness of up to 85 degrees, preferably 55 to 85 degrees, more preferably 63 to 85 degrees. The intermediate layer is formed to a hardness higher than the core surface hardness by less than 10 degrees, preferably by 1 to 8 degrees. A hardness difference of 10 degrees or more fails to provide sufficient restitution. The restitution of the core can be maintained by forming the intermediate layer to a hardness higher than the core surface hardness.

The gage, specific gravity and other parameters of the intermediate layer may be properly adjusted insofar as the objects of the invention are attainable. Preferably the gage is 0.2 to 3 mm, especially 1 to 2.5 mm and the specific gravity is 0.9 to less than 1.2, especially 0.92 to 1.18.

Since the intermediate layer 3 serves to compensate for a loss of restitution of the solid core which is formed soft, it is formed of a material having improved restitution insofar as a hardness within the above-defined range is achievable. Use is preferably made of ionomer resins such as Himilan 1557, 1601, 1605, 1855, 1856, and 1706 (manufactured by Mitsui-duPont Polychemical K.K.) and Surlyn 8120 and 7930 (E.I. duPont). A thermoplastic resin containing 10 to 100% by weight, especially 30 to 100% by weight of an ionomer resin is preferably used to form the intermediate layer.

Examples of the thermoplastic resin constructing the intermediate layer other than the ionomer resin include maleic anhydride modified ethylene-alkyl unsaturated carboxylate copolymers (e.g., HPR AR201 manufactured by Mitsui-duPont Polychemical K.K.), ethylene-unsaturated carboxylic acid-alkyl unsaturated carboxylate terpolymers (e.g., Nucrel AN4307 and AN4311 manufactured by Mitsui-duPont Polychemical K.K.), polyester elastomers (e.g.,

Hytrel manufactured by Toray-duPont K.K.), polyamide elastomers (e.g., PEBAX 3533 manufactured by Atochem), and thermoplastic elastomers having crystalline polyethylene blocks (Dynaron 6100P, HSB604, and 4600P manufactured by Nippon Synthetic Rubber K.K.) and mixtures thereof. The amount of thermoplastic resin blended is 0 to 90% by weight, preferably 0 to 70% by weight, more preferably 5 to 70% by weight of the entire intermediate layer-forming composition.

Among the above-mentioned thermoplastic resins, the thermoplastic elastomers having crystalline polyethylene blocks include three types having a molecular structure of E-EB, E-EB-E, and E-EB-S systems wherein E represents a crystalline polyethylene block, EB represents a relatively randomly copolymerized structure consisting of ethylene and butylene, and S represents a crystalline polystyrene block. These thermoplastic elastomers can be obtained by hydrogenating polybutadiene and styrene-butadiene copolymers. In addition to the thermoplastic resin including the ionomer resin, additives, for example, an inorganic filler such as zinc oxide and barium sulfate as a weight adjuster and a coloring agent such as titanium dioxide may be added to the intermediate layer-forming composition.

The cover 4 enclosing the intermediate layer 3 must have a higher hardness than the intermediate layer. The cover is formed to a JIS-C hardness of up to 95 degrees, preferably 60 to 93 degrees, more preferably 70 to 92 degrees. If the cover has a JIS-C hardness in excess of 95 degrees, the difference in hardness between the intermediate layer and the cover would be too large, leading to poor durability and hard hitting feel. The cover is formed to a hardness higher than the intermediate layer hardness by less than 15 degrees, preferably by 1 to 13 degrees. A hardness difference of 15 degrees or more would lead to poor durability and hard hitting feel.

The gage, specific gravity and other parameters of the cover may be properly adjusted insofar as the objects of the invention are attainable. Preferably the gage is 0.2 to 3 mm, especially 1 to 2.5 mm and the specific gravity is 0.9 to less than 1.2, especially 0.92 to 1.18. The gage of the intermediate layer and cover combined is preferably 2 mm or more, especially 2.5 to 5.5 mm. A total gage of less than 2 mm would lead to a lowering of durability against club strikes.

The cover composition is not critical and the cover may be formed of any of well-known stock materials having appropriate properties as golf ball cover stocks. For example, ionomer resins, polyester elastomers, and polyamide elastomers may be used alone or in admixture with urethane resins and ethylene-vinyl acetate copolymers. Ionomer resins are especially preferred while a mixture of two or more ionomer resins may be used. Preferably the cover is formed mainly of a thermoplastic resin containing 10 to 100% by weight, especially 50 to 100% by weight of an ionomer resin.

UV absorbers, antioxidants and dispersing aids such as metal soaps may be added to the cover composition if necessary. The method of applying the cover is not critical. The cover is generally formed over the core by surrounding the core by a pair of preformed hemispherical cups followed by heat compression molding or by injection molding the cover composition over the core.

Though not critical in the present invention, it is preferable to form both the intermediate layer 3 and the cover 4 from a stock material based on a thermoplastic resin containing 10 to 100% by weight of an ionomer resin. Then the cover can be more firmly joined to the intermediate layer, and this firm joint combined with the cover formed hard is effective for improving durability. In this embodiment, it is acceptable that the proportion of ionomer resin blended is different between the intermediate layer 3 and the cover 4.

The thus obtained golf ball of the invention may be formed with a multiplicity of dimples 5 in the cover surface in a conventional manner. The ball as molded may be subject to finishing steps including buffing, painting and stamping.

While the three-piece solid golf ball of the invention is constructed as mentioned above, it preferably has an overall hardness corresponding to a distortion of 2.3 to 4.3 mm, especially 2.5 to 4 mm under a load of 100 kg applied. Ball parameters including weight and diameter are properly determined in accordance with the Rules of Golf.

The three-piece solid golf ball of the invention has improved flight performance, durability, and soft pleasant hitting feel. Especially upon full shots with a driver or the like, the ball is optimized in spin rate and thus improved in flight performance and hitting feel.

EXAMPLE

Examples of the present invention are given below together with Comparative Examples by way of illustration and not by way of limitation. The amounts of components in the core, intermediate layer, and cover as reported in Tables 1 and 2 are all parts by weight.

Example and Comparative Example

Solid cores, Nos. 1 to 13, were prepared by kneading components in the formulation shown in Table 1 to form a rubber composition and molding and vulcanizing it in a mold under conditions as shown in Table 1. The cores were measured for JIS-C hardness and diameter, with the results shown in Tables 3 and 4. The JIS-C hardness of the core was measured by cutting the core into halves, and measuring the hardness at the center (center hardness) and the hardness at core surface or spherical surface (surface hardness). (The result is an average of five measurements.)

TABLE 1

Core No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Cis-1,4-polybutadiene rubber	100	100	100	100	100	100	100	100	100	100	100	100	100
Zinc acrylate	22	17	25	14	33	27	20	13	33	37	33	22	24
Zinc oxide	28.5	33	33.5	28.5	25.5	39.5	32.5	22.5	20.5	17	7	33	28.2
Dicumyl peroxide	1	1	1	1	1	1	1	1	1	1	1	1	1
*1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

TABLE 1-continued

Core No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Vulcanizing conditions													
Temperature, °C.	160	160	160	160	160	120	160	160	160	150	160	120	160
Time, min.	20	20	20	20	20	80	20	20	20	30	20	80	20

*1 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane (trade name Perhexa 3M-40 manufactured by Nippon Oil and Fats K.K.)

Next, compositions for the intermediate layer and cover were milled as shown in Table 2 and injection molded over the solid core and the intermediate layer, respectively, obtaining three-piece solid golf balls as shown in Tables 3 and 4. Whenever the intermediate layer and cover were molded, the intermediate layer and cover were measured for JIS-C hardness, specific gravity and gage. The results are also shown in Tables 3 and 4.

Ball hardness

A distortion (mm) under a load of 100 kg was measured.

Flight performance

Using a hitting machine manufactured by True Temper Co., the ball was actually hit with a driver (#W1) at a head speed of 45 m/s (HS45) and 35 m/sec. (HS35) to measure a spin, carry, and total distance.

The club used was "PRO230TITAN" having a loft angle of 11°, shaft of Harmotec Light HM50J(HK), hardness S, and balance D2 (manufactured by Bridgestone Sports Co.) for HS45 hitting and "ESSERIO" having a loft angle of 14°

TABLE 2

Intermediate layer or Cover No.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Himilan 1557*2					50					50	20				
Himilan 1601*2					50										
Himilan 1605*2	35									50		40	10		
Himilan 1855*2		50									30				
Himilan 1856*2															
Himilan 1706*2	35											30			
Himilan 1707*2												30			
Surlyn 8120*3		50		100							50		90		
HPR AR201*4	30														
Nuclel AN4307*5			36												
Nuclel AN4311*5															26
Surlyn 7930*3			32												37
Himilan AM7311*2			32												37
Hytrel 4047*6						100									
PEBAX3533*7									100						
Surlyn AD8511*3														35	
Surlyn AD8512*3														35	
Dynalon 6100P*8														30	
Titanium dioxide	4	4	4	4	4	4			4	4	4	4	4	4	4
Cis-1,4-polybutadiene rubber							100	100							
Zinc acrylate							40	36							
Zinc oxide							31	32.5							
Dicumyl peroxide							1	1							
*9							0.3	0.3							

*2 ionomer resin manufactured by Mitsui-duPont Polychemical K.K.

*3 ionomer resin manufactured by E.I. duPont of USA

*4 maleic anhydride modified ethylene-ethyl acrylate copolymer manufactured by Mitsui-duPont Polychemical K.K.

*5 ethylene-methacrylic acid-acrylate terpolymer manufactured by Mitsui-duPont Polychemical K.K.

*6 polyester elastomer manufactured by Toray-duPont K.K.

*7 polyamide elastomer manufactured by Atochem.

*8 hydrogenated polybutadiene block copolymer of E-EB-E system manufactured by Nippon Synthetic Rubber K.K.

*9 same as *1 in Table 1

The thus obtained golf balls were evaluated for hardness, flight performance, spin, feel, and durability by the following tests.

and shaft hardness R (manufactured by Bridgestone Sports Co.) for HS35 hitting.

Feel

Five golfers with a head speed of 45 m/sec. (HS45) and five golfers with a head speed of 35 m/sec. (HS35) actually hit the balls. The ball was rated according to the following criterion.

O: soft

Δ: ordinary

X: hard

Durability

Durability against continuous strikes and durability against cutting were evaluated in combination. The ball was rated according to the following criterion.

O: excellent

Δ: ordinary

X: inferior

TABLE 3

Examples		1	2	3	4	5	6	7
Core	Type	1	2	3	4	5	1	13
	Center hardness A (JIS-C)	63	55	63	52	65	63	66
	Surface hardness B (JIS-C)	74	70	74	66	80	74	76
	Hardness difference B-A (JIS-C)	11	15	11	14	15	11	10
	Diameter (mm)	36.5	36.1	35.1	37.9	36.5	36.5	36.5
Intermediate layer	Type	A	B	C	D	E	N	N
	Hardness C (JIS-C)	76	75	80	70	84	80	80
	Hardness difference from core surface C-B (JIS-C)	2	5	6	4	4	6	4
	Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	Gage (mm)	1.6	1.6	1.8	1.2	1.6	1.6	1.6
Cover	Type	C	E	J	K	J	O	O
	Hardness (JIS-C)	80	84	86	76	86	86	86
	Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	Gage (mm)	1.5	1.7	2.0	1.2	1.5	1.5	1.5
Ball (entirety)	Diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7	42.7
	Hardness @ 100 kg (mm)	3.0	3.4	2.8	3.7	2.6	3.0	2.9
#W1/HS45	Spin (rpm)	2800	2650	2750	2700	2900	2780	2720
	Carry (m)	209.0	209.0	210.0	208.5	210.5	209.8	210.0
	Total (m)	223.0	223.5	224.5	222.0	224.0	224.0	225.0
	Feel	O	O	O	O	O	O	O
#W1/HS35	Spin (rpm)	4600	4400	4550	4700	4650	4595	4510
	Carry (m)	143.0	144.0	143.5	144.0	143.0	143.3	144.5
	Total (m)	150.0	153.0	150.0	152.5	152.0	149.9	154.0
	Feel	O	O	O	O	Δ	O	O
Durability		O	O	O	O	O	O	O

TABLE 4

Comparative Examples		1	2	3	4	5	6	7
Core	Type	6	7	8	9	10	11	12
	Center hardness A (JIS-C)	72	59	50	65	77	65	67
	Surface hardness B (JIS-C)	74	74	65	80	86	80	69
	Hardness difference B-A (JIS-C)	2	15	15	15	9	15	2
	Diameter (mm)	33.7	33.7	33.3	38.3	38.7	30.1	35.5
Intermediate layer	Type	C	F	G	—	B	H	I
	Hardness C (JIS-C)	80	64	86	—	75	80	67
	Hardness difference from core surface C-B (JIS-C)	6	−10	21	—	−11	0	-2
	Specific gravity	0.97	1.12	1.25	—	0.97	1.25	1.01
	Gage (mm)	2.5	2.5	2.5	—	0.8	4.1	1.8
Cover	Type	J	K	K	L	K	K	M
	Hardness (JIS-C)	86	92	92	92	92	92	71
	Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	Gage (mm)	2.0	2.0	2.2	2.2	1.2	2.2	2.0
Ball (entirety)	Diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7	42.7
	Hardness @ 100 kg (mm)	2.1	3.4	2.9	3.0	2.2	2.5	2.9
#W1/HS45	Spin (rpm)	3100	2650	2600	2600	3200	2700	3300
	Carry (m)	206.0	207.0	207.0	206.5	207.0	205.0	205.0
	Total (m)	219.0	222.0	221.0	220.0	219.5	220.0	217.0
	Feel	X	O	O	O	X	Δ	O
#W1/HS35	Spin (rpm)	4750	4200	4300	4300	4800	4500	4900
	Carry (m)	138.0	140.0	139.0	137.0	136.0	134.5	135.0
	Total (m)	145.0	149.0	148.0	147.0	141.0	141.0	140.0
	Feel	X	O	Δ	O	X	X	O
Durability		O	X	X	X	Δ	Δ	O

As is evident from Tables 3 and 4, in Comparative Examples 1 and 7, the core does not have an optimum hardness distribution since the difference between core surface hardness and core center hardness is small. Additionally, in Comparative Example 7, the core surface is harder than the intermediate layer. In Comparative Examples 2, 5, and 6, the core surface is harder than or equal to the intermediate layer. In Comparative Example 3, the intermediate layer is harder than the core surface. Comparative Example 4 is a two-piece solid golf ball. In Comparative Example 5, both the core center and surface are hard. For these factors, the golf balls of Comparative Examples 1 to 7 fail to fully satisfy some or all of flight distance, feel, durability and appropriate spin rate upon full shots with a driver or show considerably inferior results.

In contrast, the golf balls of Examples 1 to 7 within the scope of the invention were acknowledged to produce an appropriate spin rate upon full shots with a driver to cover a longer flight distance and be excellent in both hitting feel and durability.

We Claim:

1. A three-piece solid golf ball of the three-layer structure comprising, a solid core, an intermediate layer, and a cover, wherein the solid core, intermediate layer, and cover each have a hardness as measured by a JIS-C scale hardness meter wherein the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 5 to 25 degrees, the intermediate layer hardness being higher than the core surface hardness by less than 10 degrees, and the cover hardness being higher than the intermediate layer hardness wherein said solid core is formed of an elastomer comprising cis-1,4-polybutadiene as a main component and the core has a diameter of 34 to 41 mm.

2. The three-piece solid golf ball of claim 1 wherein said intermediate layer is based on a thermoplastic resin containing 10 to 100% by weight of an ionomer resin and has a hardness of up to 85 degrees as measured by the JIS-C scale hardness meter.

3. The three-piece solid golf ball of claim 1 wherein said intermediate layer has a gage of 0.2 to 3 mm and a specific gravity of 0.9 to less than 1.2.

4. The three-piece solid golf ball of claim 1 wherein said cover is based on a thermoplastic resin containing 10 to 100% by weight of an ionomer resin and has a hardness of up to 95 degrees as measured by the JIS-C scale hardness meter.

5. The three-piece solid golf ball of claim 1 wherein said cover has a gage of 0.2 to 3 mm and a specific gravity of 0.9 to less than 1.2.

6. The three-piece solid golf ball of claim 1 wherein said intermediate layer and said cover combined have a total gage of at least 2 mm.

7. The three-piece solid golf ball of claim 1 wherein said core center hardness is in the range of 50 to 70 on JIS-C and the surface hardness of said core is in the range of 62 to 83 on JIS-C.

8. The three-piece solid golf ball of claim 1 wherein said core surface hardness is higher than the core center hardness by 7 to 22 degrees on JIS-C.

9. The three-piece solid golf ball of claim 1 wherein said solid core has an overall distortion in the range of 2.5 to 4.8 mm under an applied load of 100 kg.

10. The three-piece solid golf ball of claim 1 wherein said intermediate layer has a hardness greater than the core surface hardness by less than 1 to 8 degrees on JIS-C.

11. The three-piece solid golf ball of claim 1 wherein said intermediate layer has a gage in the range of 1 to 2.5 mm and a specific gravity in the range of 0.92–1.18.

12. The three-piece solid golf ball of claim 1 wherein said cover has a hardness in the range of 60 to 93 degrees on JIS-C.

13. The three-piece solid golf ball of claim 1 wherein said cover has a gage in the range of 1.0 to 2.5 mm and a specific gravity in the range of 0.92 to 1.118.

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US006390935B1

(12) **United States Patent**
Sugimoto

(10) **Patent No.:** **US 6,390,935 B1**
(45) **Date of Patent:** ***May 21, 2002**

(54) **THREE-PIECE GOLF BALL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(52) **U.S. Cl.** 473/373; 473/374
(58) **Field of Search** 473/373, 374, 473/376, 367, 368

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(57) **ABSTRACT**

The present invention provides a three-piece golf ball which has an improved controllability at an approach shot while maintaining a long flight distance inherent to a solid golf ball. In the three-piece golf ball, the hardness, the specific gravity, and deformation amounts of the center and the core are determined in consideration of the relationship between each other.

5 Claims, 1 Drawing Sheet

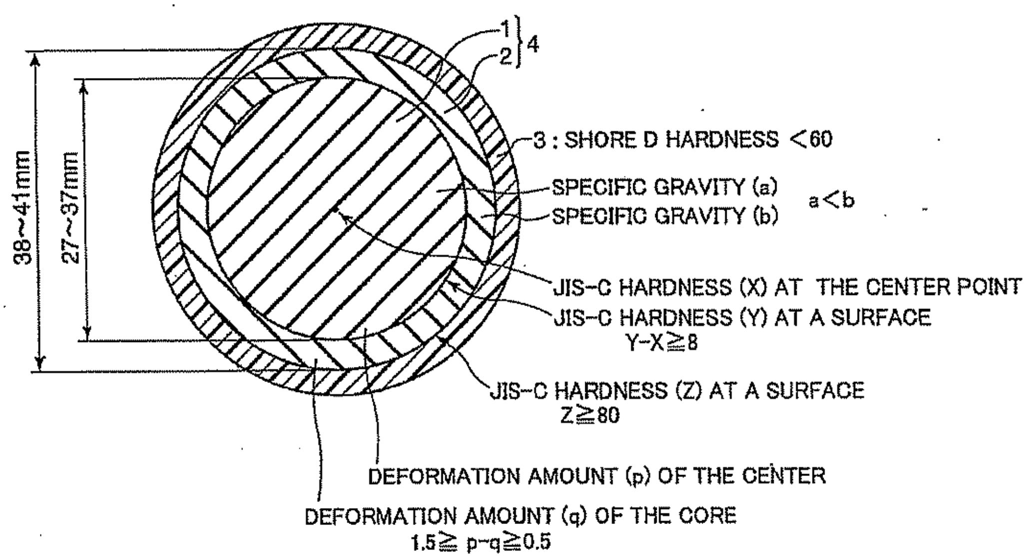
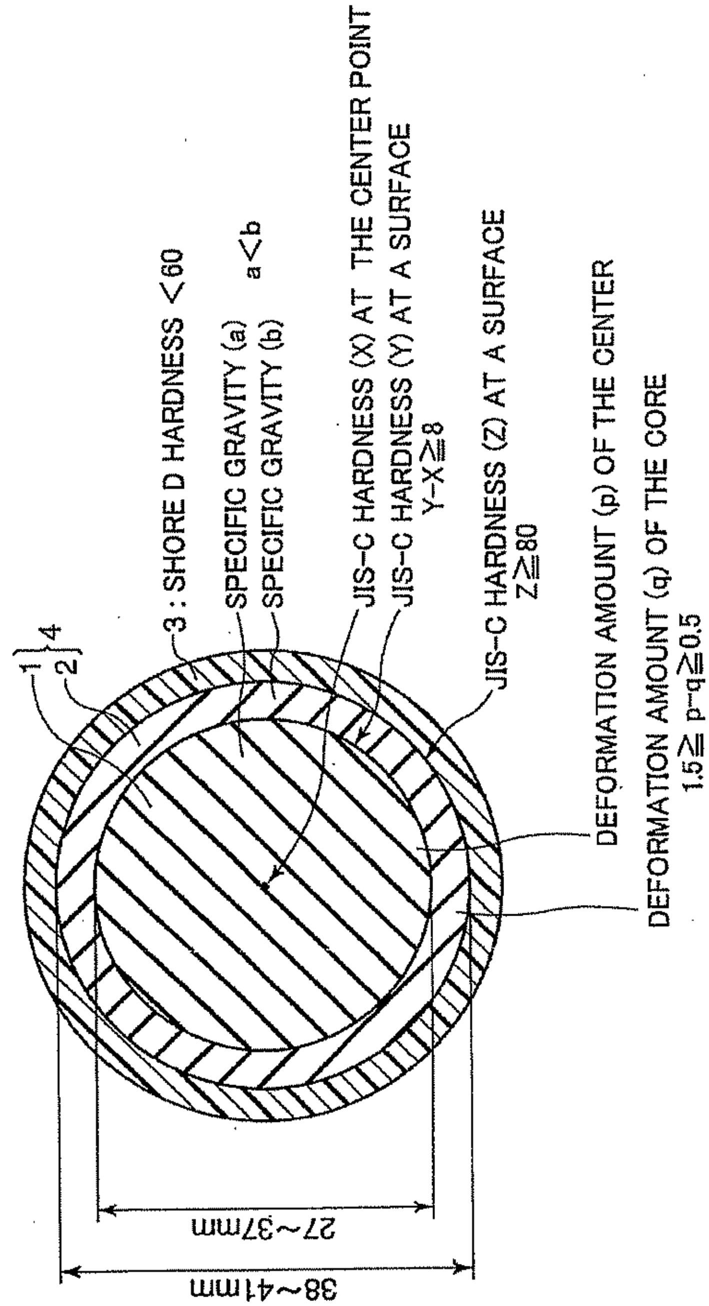


FIG.1



1
2
4
3 : SHORE D HARDNESS <60
SPECIFIC GRAVITY (a)
SPECIFIC GRAVITY (b)
a<b
JIS-C HARDNESS (X) AT THE CENTER POINT
JIS-C HARDNESS (Y) AT A SURFACE
Y-X≧8
JIS-C HARDNESS (Z) AT A SURFACE
Z≧80
DEFORMATION AMOUNT (p) OF THE CENTER
DEFORMATION AMOUNT (q) OF THE CORE
1.5≧ p-q≧0.5
27~37mm
38~41mm

THREE-PIECE GOLF BALL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a three-piece golf ball suitable for both skilled golfers and high handicap players. More specifically, the present invention relates to a three-piece golf ball which has an improved controllability at an approach shot and an improved shot feeling while maintaining excellent flight performance inherent to a solid golf ball.

2. Description of the Prior Art

Hitherto, a thread-wound golf ball and a two-piece golf ball have been generally used. A thread-wound golf ball comprises a core formed by winding a rubber thread around a solid rubber ball (i.e. a solid center) or a rubber bag filled with a liquid (i.e. a liquid center), and a cover enclosing the core. A conventional two-piece golf ball comprises a core made of rubber, and a cover enclosing the core and the core is made of synthetic resin such as ionomer.

A thread-wound golf ball provides a good shot feeling (i.e. soft feel when hitting the ball) because of the cover made of a soft material such as balata and has an excellent controllability due to high spin rate. However, the thread-wound golf ball may not attain a long flight distance in a head wind, especially when hit by golf players with a low club head speed including beginner, female, and the like. Moreover the thread-wound golf ball is poor in durability.

On the other hand, two-piece golf balls have superior durability to thread-wound golf balls and may attain a long flight distance in a head wind, since two-piece golf balls have high resilience and show difficulty to impart intentional spin. Higher resilience can lead to longer flight distance, however the difficulty to impart the spin on the two-piece golf ball causes poor controllability, for example a long run on a green at an approach shot.

A long flight distance is beneficial to high handicap players, and therefore they prefer golf balls having high resilience. Contrarily, excellent controllability is beneficial to more skilled players, especially professional golfers, and therefore they prefer golf balls on which intentional spin can be imparted. Since conventional two-piece golf balls cannot satisfy both the goals of a long flight distance and good controllability, two kinds of two-piece golf balls are produced: one can attain a long flight distance with poor controllability, and the other can provide a good controllability with sacrificing long flight distance.

However, there is a large demand for a golf ball which has a good controllability while maintaining a sufficient flight distance. As a golf ball which meets this demand, three-piece golf balls have been suggested. A three-piece golf ball comprises a core consisting of an center, an outer shell placed on the center, and a cover placed on the outer shell.

For example, Japanese Unexamined Patent Publication No. 59-194760 discloses a three-piece golf ball. In the three-piece golf ball, the hardness of the center is increased from the center point toward a surface of the center, and the specific gravity of the center is larger than that of the outer shell. The three-piece golf ball is liable to spin comparing with a two-piece golf ball, but cannot attain a sufficient flight distance to satisfy golfers who desire a long flight distance, especially when hit by a driver. Japanese Unexamined Patent Publication No. 10-57523 also suggests a three-piece golf ball in which the specific gravity of the center is smaller than that of the outer shell. In the three-piece golf ball, the ratio of deformation amount of the core (the center and the

outer shell placing on the center) to that of the center alone (i.e. the deformation amount of the core/the deformation amount of the center alone) is in the range of 0.75 to 1. The three-piece golf ball has a such property that there is small difference between the hardness at a surface of the core and the hardness at the center point of the center, and has high spin rate. As a result, a flight distance is impaired, and therefore golfers who desire a longer flight distance cannot be satisfied with the three-piece golf ball.

In order to solve the problems of conventional three-piece golf balls, the present invention provides a three-piece golf ball which can offer an excellent controllability and a good shot feeling, and also can attain a long flight distance.

SUMMARY OF THE INVENTION

The present invention provides a three-piece golf ball which comprises a center having a diameter(d_1) of 27 to 37 mm and a specific gravity (a), an outer shell placed on the center and having a larger specific gravity (b) than the specific gravity (a), and a cover placing on the outer shell and having a Shore D hardness of less than 60. The center has a JIS-C hardness (X) at the center point thereof and a JIS-C hardness (Y) at a surface thereof satisfying the equation: $(Y-X) \geqq 8$. The center and the outer shell constitute the core of the three-piece golf ball, and the core has a JIS-C hardness (Z) at a surface thereof being 80 or larger. When a load from 10 kgf as an initial load to 130 kgf as a final load apply to the center and the core respectively, a deformation amount (p) of the center and a deformation amount (q) of the core satisfy the equation: $(p-q) \geqq 0.5$.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of a three-piece golf ball of the present invention. The three-piece golf ball comprises an center 1, an outer shell 2 placing on the center 1 and a cover 3 placing on the outer shell 2. The center 1 and the outer shell 2 constitute a core 4.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, the respective elements of the three-piece golf ball of the present invention (i.e. the center 1, the outer shell 2 and the cover 3) will be described.

First, the center 1 will be described. The center 1 is made of a material containing rubber as a main component, and has a diameter (d_1) of 27 to 37 mm. The resilience of the golf ball is mainly determined by the resilience of the center 1. For the purpose of ensuring higher resilience of the golf ball, the diameter (d_1) should be 27 mm or more. In addition, in order to lessen impact to a player when hitting the golf ball and provide a good shot feeling, the diameter (d_1) of at least 27 mm is necessary to vary the hardness of the center 1 from its center point to its surface mildly. On the other hand, considering the standard size of a golf ball, it is necessary to decrease the thickness of the outer shell 2 as the diameter (d_1) increases. In order to obtain a sufficient effect of comprising the outer shell 2 in the golf ball, the upper limit of the diameter (d_1) is required to be 37 mm.

As long as the equations required in the present invention, the hardness of the center 1 may vary as follows: the hardness is gradually increased from its center point to its surface; the hardness is gradually increased from its center point to the middle point of the center 1 (i.e. at the point corresponding to the diameter of about 15 mm), and decreased gradually from the middle point to the surface

such that the hardness at the surface is kept higher than that of the center point.

According to the invention, a JIS-C hardness of the center point of the center 1 (hereinafter, referred to as "a center point hardness (X)") and a JIS-C hardness at a surface of the center 1 (hereinafter, referred to as "a center surface hardness (Y)") satisfy the equation: $(Y-X)\geqq 8$, preferably satisfy the equation: $(Y-X)\geqq 10$. If (Y–X) is smaller than 8 by increasing the center point hardness (X), the resulting golf ball gives a heavy shot feeling when hit by a golf club, for example a driver, having such a property that the shot feeling largely depends on the hardness of the center point of the golf ball. Players feel the shot feeling heavy in the case that the contact time of the golf ball and the club head is longer after hitting the ball. If (Y–X) is smaller than 8 by decreasing the center surface hardness (Y) while a JIS-C hardness (Z) at a surface of the core 4 (hereinafter, referred to as "core hardness (Z)") is 80 or larger, the difference between the center surface hardness (Y) and the hardness of the outer shell layer 2 alone becomes too large. The resulting golf ball exhibit poor durability and cannot attain a long flight distance due to too large back spin. The preferable upper limit of (Y–X) is 25 or smaller, and more preferably 20 or smaller as a following reason. If (Y–X) becomes too large by decreasing the center point hardness (X), the resulting golf ball has poor resilience. If the difference (Y–X) becomes too large by increasing the center surface hardness (Y), the shot feeling of the resulting golf ball becomes worse.

In order to adjust the difference between the center surface hardness (Y) and the center point hardness (X), i.e. (Y–X), within the range of 8 to 25 and being the core surface hardness of 80 or larger, the center point hardness (X) is preferably 55 to 75, and more preferably 58 to 72. If the center point hardness (X) is smaller than 55, the center 1 becomes too soft and the resilience of the golf ball is lowered. Contrary to this, if the center point hardness (X) is larger than 75, the center 1 becomes too hard and the shot feeling of the golf ball becomes worse. The center surface hardness (Y) is preferably 70 to 90, and more preferably 73 to 87. If the center surface hardness (Y) is smaller than 73, the center 1 becomes too soft and the resilience of the golf ball is lowered. Contrary to this, if the center surface hardness (Y) is larger than 87, the center 1 becomes too hard and the shot feeling of the golf ball is impaired.

The specific gravity of the center 1 (hereinafter, referred to as "specific gravity (a)") is preferably 1.0 to 1.2, and more preferably 1.00 to 1.15, and the most preferably 1.00 to 1.10. The reason why the specific gravity (a) is made to 1.0 or larger is as follows. The center 1 is made of a rubber composition containing diene rubber as a main component and vulcanizing agents such as peroxide. The diene rubber usually has a specific gravity of about 1.0, and a conventional vulcanizing agent has a specific gravity of 1.0 or larger. When the diene rubber and the vulcanizing agent are blended to prepare the rubber composition, the specific gravity of the rubber composition inevitably becomes 1.0 or larger. Therefore, it is difficult to adjust the specific gravity (a) of the center 1 to less than 1.0, unless hollow portions or vacancies are formed in the center 1. The preferable upper limit of the specific gravity (a) is 1.2, because in order to increase resilience, it is necessary to use large amount of the rubber and small amount of fillers to prepare the composition for the center 1.

When a load ranging from 10 kgf as an initial load to 130 kgf as a final load is applied onto the center 1, the deformation amount of the center 1 (hereinafter, referred to as "center deformation amount (p)") is preferably 3.0 to 5.0 mm, and more preferably 3.75 to 4.35 mm. If the center deformation (p) is less than 3.0 mm, the center 1 is too hard to provide the golf ball giving a good shot feeling because of giving a big impact to the player. If the center deformation (p) is larger than 5.0 mm, the center 1 is soft enough to deform exceedingly when the ball is hit, thereby being liable to detach from the hard cover 3 by repeated hit and causing impairing durability of the golf ball.

The center 1 is made of a vulcanized rubber composition which contains a base rubber, a vulcanization initiator and a crosslinking agent, but other material may be used as far as it satisfies the above-described requirements.

As the base rubber in the center composition, either a natural rubber or a synthetic rubber may be used as far as it is diene rubber conventionally used for a core of a solid golf ball. Examples of synthetic rubber include ethylene propylene diene terpolymer (EPDM), butadiene rubber (BR), isoprene rubber (IR), styréne butadiene rubber (SBR), and acrylonitrile butadiene rubber (NBR). These may be used alone or in combination of two or more of them. Among them, preferable is cis-1,4-polybutadiene having 40 percent or more, and more preferably 80 percent or more of cis 1,4-bonds.

As the vulcanization initiator, an organic peroxide is used. Examples of the organic peroxide include dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,5-trimethyl cyclohexane, 2,5-dimethyl-2,5-di(t-butyl peroxy)hexane, and di-t-butylperoxide. Among them, dicumyl peroxide is preferable. The amount of the organic peroxide is preferably 0.3 to 2.0 parts by weight, and more preferably 0.5 to 2.0 parts by weight per 100 parts by weight of the base rubber.

As the co-crosslinking agent, an α,β-unsaturated carboxylic acid having 3 to 8 carbon atoms or a metal salt thereof are used. Preferred is the α,β-unsaturated carboxylic acid such as acrylic acid and methacrylic acid, and the univalent or divalent metal salts such as zinc salt or magnesium salt Among them, zinc acrylate is more preferable because it imparts high resilience to the resulting golf ball. The amount of the α, β-unsaturated carboxylic acid or metal salt thereof is preferably 20 to 40 parts by weight, and more preferably 25 to 35 parts by weight, and the most preferably 24 to 33 parts by weight per 100 parts by weight of the base rubber. If the amount is larger than 40 parts by weight, the rubber composition is crosslinked too densely to produce the center 1 having a hardness of 75 or smaller. Contrary to this, if the amount is smaller than 20 parts by weight, the center composition is not crosslinked enough to produce a center having a sufficient resilience as a solid golf ball.

On top of the above-described essential components, the rubber composition for the center may contain additives which have been conventionally used for forming a core of solid golf balls, if necessary. Examples of the additives include a specific gravity adjuster, an antioxidant, a plasticizer, a dispersant, a UV absorber, a colorant, and a peptizer. In order to attain high resilience without impairing the shot feeling, an organic sulfide compound such as diphenyl disulfide may be admixed.

Next, the outer shell 2 will be described.

The thickness of the outer shell 2 is preferably 1 to 14 mm, and more preferably 2 to 6 mm, considering that the center 1 has a diameter (d_1) of 27 to 37 mm, and the core 4 has a diameter (d_2) of 38 to 41 mm.

According to the present invention, the outer shell 2 has a specific gravity (b) which is larger than the specific gravity (a) of the center 1 for the following reason. In order to achieve higher resilience of the golf ball, the preferable

upper limit of the specific gravity (a) is 1.2, since the center 1 has an important influence on the resilience of the golf ball. Therefore, in order to have the resulting golf ball meet the standard weight, it is necessary to produce the outer shell having a specific gravity (b) which is larger than the specific gravity (a). Even if the rubber content in the outer shell composition is decreased, no problem occurs because the specific gravity (b) has less influence on the resilience of the golf ball than the one of the center 1. The difference between the specific gravity (a) and the specific gravity (b) is preferably 0.1 or larger (i.e. (b−a)≧0.1), and more preferably 0.15 or larger (i.e. (b−a)≧0.15). The upper limit of (b−a) is preferably 0.3, and more preferably 0.25. Preferable specific gravity (b) is in the range of 1.10 to 1.35, and more preferably 1.15 to 1.30. If (b−a) is less than 0.1 while having the resulting golf ball met the standard weight, the content of the base rubber in the center composition is required to be decreased such that the specific gravity (a) is under 1.2. The resulting golf ball does not have sufficient resilience to attain a long flight distance. On the other hand, if the (b−a) is larger than 0.3, the specific gravity (b) should be larger than 1.30 because the center has usually a specific gravity (a) of at least 1.0. Using the outer shell having the specific gravity (b) of larger than 1.3, it is difficult to produce the golf ball having a weight under the standard maximum weight limitation (45.92 kg).

As the material for the outer shell 2, a rubber composition comprising a base rubber, a vulcanization initiator, a co-crosslinking agent, and a specific gravity adjuster are used, but it is not limited thereto as far as it satisfies the above requirements and requirements for the core 4 described below.

Above-mentioned three materials (base rubber, vulcanization initiator, and co-crosslinking agent) used in the center composition may be also used in the rubber composition for the outer shell 2. On top of the three materials, the specific gravity adjuster is blended in the outer shell composition in order to have the specific gravity (b) of the outer shell 2 adjusted in the range of 1.10 to 1.35. As the specific gravity adjuster, an inorganic salt such as zinc oxide, barium sulfate, calcium carbonate; metal powders of zinc oxide, barium sulfate, and/or tungsten; and a mixture of two or more of them may be used. Even if the same kind of base rubber, vulcanization initiator, and co-crosslinking agent as those employed for the center 1 are used in the outer shell composition, the outer shell 2 may have various hardness by changing their blending ratio and vulcanization conditions (e.g. vulcanizing temperature, vulcanizing time or the like).

On top of the above components, additives which are conventionally used for producing a core of solid golf balls may be admixed in the outer shell composition, if necessary. Examples of the additives include an antioxidant, a plasticizer, a dispersant, a UV absorber, a colorant, and a peptizer. In order to attain higher resilience without impairing the shot feeling, an organic sulfide compound such as diphenyl disulfide may be added.

The center 1 is covered with the outer shell 2 to form the core 4. That is, the core 4 of the present invention consists of the center 1 which has a diameter (d_1) of 27 to 37 mm, a specific gravity (a), a center surface hardness (Y) and a center point hardness (X) satisfying the equation: (Y−X)≧8, and a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto; and the outer shell 2 which has a larger specific gravity (b) than the specific gravity (a). And the core 4 has a JIS-C hardness (Z) at a surface thereof being 80 or larger and a deformation amount (q) of the core when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto, and the deformation amount (q) satisfying the equation: (p−q)≧0.5.

According to the present invention, the JIS-C hardness (Z) at a surface of the core 4 (corresponding to a hardness at a surface of the outer shell 2, simply referred to as "a core hardness (Z)") is 80 or more, preferably 82 or more. If the core hardness (Z) is less than 80, the resulting golf ball does not have sufficient resilience to attain a long flight distance. The core hardness (Z) is preferably 95 or smaller, more preferably 90 or smaller. If the core hardness (Z) is larger than 95, the core 4 becomes too hard to provide a golf ball giving a good shot feeling. The difference between the core harness (Z) and the center point hardness (X) is preferably 10 or more (i.e. (Z−X)≧10), and more preferably 15 or more (i.e. (Z−X)≧15), and the most preferably 20 or more (i.e. (Z−X)≧20). The preferable upper limit of (Z−X) is 35, and more preferably 30. If (Z−X) is less than 10, the resulting golf ball flies at a low launch angle and high spin rate especially when hit by a driver, a middle iron and a long iron. Consequently, a long flight distance cannot be attained. Contrary to this, if (Z−X) is larger than 35, the center point hardness (X) differ greatly from the hardness of the outer shell 2 alone. In this case, the center 1 is soft enough to deform greatly, but the outer shell 2 cannot deform as much as the center 1. Thereby the center 1 is liable to detach from the outer shell 2 and resulting in poor durability.

When a load ranging from 10 kgf as an initial load to 130 kgf as a final load is applied onto the center 1 and the core 4, the respective amounts of deformation thereof are simply referred to as "a center deformation (p)" and "a core deformation (q) respectively. According to the present invention, the core deformation (q) is smaller than the center deformation (p), and the center deformation (p) and the core deformation (q) satisfy the equation: (p−q)≧0.5, preferably satisfy the equation: (p−q)≧0.65. If (p−q) is less than 0.5, the golf ball flies at a low launch angle and high spin rate especially when hit by a driver, and thereby a long flight distance cannot be attained. The preferable upper limit of (p−q) is 1.50, and more preferably 1.00. If (p−q) is larger than 1.50, the resulting golf ball is poor in durability because the center 1 is liable to detach from the outer shell 2.

As mentioned above, the preferred core 4 which has a diameter (d_2) of 38 to 41 mm and consists of a center having a diameter (d_1) of 27 to 37 mm, a specific gravity (a), a JIS-C hardness (X) at the center point thereof, JIS-C hardness (Y) at a surface thereof satisfying the equation: 8≦(Y−X)≦25, and a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load to the center; and an outer shell placed on the center, having specific gravity (b) satisfying the equation: 0.1≦(b−a)≦0.3. The core has a JIS-C hardness (Z) of 80 or larger, which satisfies the equation: 10≦(Z−X)≦35, and a deformation amount (q) of the core satisfies the equation: 0.5≦(p−q) ≦1.5, when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto.

Next, the cover 3 will be described.

The cover 3 is usually made of a material containing ionomer as a main component. A shore D hardness of the cover 3 (hereinafter, simply referred to as "a cover hardness D") is less than 60, and preferably 58 or less. If the cover hardness D is not less than 60, the sufficient spin to stop quickly on green cannot be put on the golf ball at an approach shot. The preferable lower limit of the cover hardness D is 45, and more preferably 48. The softer cover (i.e. the cover hardness D is smaller than 45) allows to

impart too high spin on the golf ball when hit by a driver, a long iron, or a middle iron. As a result, a long flight distance cannot be attained.

The thickness of the cover 3 is preferably 0.9 to 2.4 mm, and more preferably 1.5 to 2.3 mm, considering the standard size of the golf ball and the above-mentioned size of the core 4.

The material for the cover 3 is not specifically limited as far as it satisfies the above requirements. Preferably, a composition containing ionomer as a main component is used.

Ionomers are copolymers of an olefin and an α, β-etylenically unsaturated carboxylic acid with a portion of the carboxylic acid groups neutralized by a metal ion. The metal ions are univalent metal ions such as sodium ion, potassium ion, and lithium ion; divalent metal ions such as zinc ion calcium ion, magnesium ion, copper ion, and manganese ion; trivalent metal ions such as aluminum ion, and neodymium ion. Preferred are sodium ion and lithium ion, and magnesium ion, because they may provide a hard ionomer having high hardness and high resilience.

Specific examples of the ionomer include: ionomers sold by Mitui DuPont Chemical Co.,Ltd. such as Himilan® 1605 (an ionomer resin of sodium ion-neutralized ethylene-methacrylic acid copolymer), Himilan® 1707 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Himilan® 1706 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Himilan® AM7315 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Himilan® AM7317 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Himilan(® 1555 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Himilan 1557 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer); ionomers sold by Exxon Chemical Co., Ltd such as Iotek® 8000 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Iotek® 7010 (an ionomer of a zinc ion-neutralized ethylene-methacrylic acid copolymer); ionomers sold by DuPont Co., Ltd such as Surlyn® 7930 (an ionomer resin of a lithium ion-neutralized ethylene-methacrylic acid copolymer), Surlyn® 8511 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Surlyn® 8512 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Surlyn® 8945 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), and Surlyn 9945 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer).

The cover composition contains the above-mentioned ionomer as a main component, and preferably, further contains a thermoplastic elastomer because the thermoplastic elastomer can provide a softer cover which can deform in response to the deformation of the core 4. The thermoplastic elastomer is a block copolymer formed by bonding a polymer block which shows a freeze phase or a crystalline phase at a melting point or lower, or a polymer block in which the movement of the molecules is restricted by hydrogen bonding (i.e. hard segment), and a polymer block in which the movement of the molecules is not restricted under the melting point (i.e. soft segment). Defining the hard segment as H and the soft segment as S, H and S may link in the form of H-S, H-S-H, or a multi-block form or a star-form expressed by $(H\text{-}S)_n$. Specific examples of the thermoplastic elastomer include: polystyrene elastomers in which the hard segment is polystyrene, and the soft segment is selected from the group of polybutadiene, polyisoprene, and hydrogenated products thereof; polyolefin elastomers in which the hard segment is polyethylene or polypropyrene, and the soft segment is butyl rubber or ethylene-propyrene-diene terpolymer (EPDM); polyamide elastomers in which the hard segment is polyamide, and the soft segment is polyester or polyether; polyester elastomers in which the hard segment is polyester, and the soft segment is polyether; polyurethane elastomers in which the hard segment is a polyurethane block having urethane bonds, and the soft segment is polyester or polyether; elastomers in which polybutadiene block has epoxy groups, or elastomers in which polystyrene block has a hydroxyl group at the terminal thereof; and a mixture of two or more of these elastomers.

On top of the ionomer and the thermoplastic elastomer described above, the cover composition may further contain other additives, if necessary. Examples of the additives include a colorant, an antioxidant, a dispersant, and a UV absorber.

In the production of the three-piece golf ball, the center 1 is produced first, and the center 1 is covered with the outer shell 2 and the cover 3 in this order. The center 1 is formed by vulcanization in a mold under heat and pressure. The outer shell 2 and the cover 3 are formed by a conventional method for forming golf ball cover well known in the art, such as injection molding, compression molding and the like. In the compression molding, two preformed half-shells are prepared, and the molded center is put into one of them, and then the half-shells are combined together into a shape of ball to form the core. In forming the cover by the compression molding, the molded core is put into one of preformed half-shells made of cover material, and then the half-shells are combined together to form cover.

In forming a cover on the core, dimples or brambles are impressed onto the surface of the cover. After cover forming, paint finishing and mark stamping may be provided on the surface for serving commercial sale.

In the three-piece golf ball of the present invention, the hardnesses, the specific gravity, and deformation amounts of the center and the core are determined in consideration of the relationship between each other in order to provide the solid golf ball which can satisfy both of golfers desired a long flight distance and golfers desired an excellent controllability. In addition, the three-piece golf ball gives excellent shot feeling. Therefore, by use of three-piece golf ball of the present invention, players may obtain a long flight distance while receiving less impact. Furthermore the three-piece golf ball has excellent durability inherent to solid golf balls.

EXAMPLES

Methods of Measurement and Eevaluation

① Hardness (Degree)

a) JIS-C hardness of center and core

The hardness of the center was measured at the center point of the center, at points 5 mm, 10 mm and 15 mm from the center, and at a surface of the center. The hardness of the core was measured at the surface thereof.

The JIS-C hardness was measured by a C-type spring hardness meter in accordance with JIS-K6301.

b) Shore D hardness of cover

The hardness of a cover was measured at a surface of the golf ball produced described below by using a Shore D-type spring hardness meter in accordance with ASTM-D 2240-68.

② Amount of deformation (mm)

A load ranging from 10 kgf as an initial load to 130 kgf as a final load was applied to the center, and the deformation amount (p) of the center was measured. A load ranging from 10 kgf as an initial load to 130 kgf as a final load was applied to the core, and the deformation amount (q) of the core was measured.

③ Resilience

A metal cylinder was hit against the golf ball, and the resiliences of the cylinder and the golf ball were respectively measured at the moment of hit. The higher the measured value, the better the resilience was.

④ Flight Performance when Hit by a Driver

The golf ball was hit by a driver, and the launch angle, spin rate, flight distance (carry and total distance) were measured.

a) Launch Angle (°)

A W#1 driver having a metal head was mounted to a swing robot manufactured by True Temper Co., Ltd. and the golf ball was hit by the driver at a head speed of 45 m/sec. The angle immediately after the golf ball was hit was measured. The measurement was repeated 8 times, and the average value was obtained.

b) Spin (rpm)

A W#1 driver having a metal head was mounted to a swing robot manufactured by True Temper Co., Ltd. and the golf ball was hit by the driver at a head speed of 45 m/sec. The amount of back spin immediately after the golf ball was hit was measured. The measurement was repeated 8 times, and the average value was obtained.

c) Flight Distance (yard)

A W#1 driver having a metal head was mounted to a swing robot manufactured by True Temper Co., Ltd. and the golf ball was hit by the driver at a head speed of 45 m/sec. The distance from the point where the ball was hit to the point where the ball fell to the ground was measured (i.e. carry). At the same time, the distance from the point where the ball fell to the ground to the point where the ball stopped was measured (i.e. run). The carry and the run was summed up to obtain the total distance. The measurement was repeated 5 times, and the average value was obtained.

⑤ Controllability when Hit by an Iron

The controllability was evaluated from the amount of spin, and a flight distance (i.e. carry and run).

A spin rate and a flight distance were measured respectively in the same manner as those when hit by a driver with the exception that an iron (SW) was used instead of a driver and the ball was hit at an initial speed of 21 m/sec.

⑥ shot feeling

Each of ten professional golfers hit the golf ball using a W#1 driver having a metal head, and judged the shot feeling under the following criteria. The most prevailing judge was adopted as the shot feeling of the golf ball.

◎: the impact was very small (very soft feel);

○: the impact was small (soft feel);

Δ: the impact was not small (rather hard feel); and

×: the impact was very large (hard feel).

Production of Golf Ball

The center for the golf ball of Example 1 was prepared by the following steps. The rubber composition for the center

shown in Table 1 was uniformly kneaded by a kneading roll, and then, was vulcanized and molded to form a center in the spherical shape having a diameter (d_1) of 28 mm. Repeating these steps, the centers of the golf balls of Examples 2 to 4 in the spherical shape having a diameter (d_1) of 28 to 35 mm were produced using the compositions shown in Table 1, and the centers of Comparative Examples 1 to 7 in the spherical shape having a diameter (d_1) of 25 to 35 mm were produced using the compositions shown in Table 2. The JIS-C hardness, specific gravity, and amount of deformation of the respective centers were measured by the methods described above. The results of measurement for the centers of Examples 1 to 4 are shown in Table 4, and those for Comparative Examples 1 to 7 are shown in Table 5.

Next, the core of the golf ball of Example 1 was formed by the following steps. By use of the composition for the outer shell shown in Table 1, the outer shell was formed on the center by injection molding. As a result, a core having a diameter (d_2) of 39.1 mm was produced. Repeating these steps, the core of the golf balls of Examples 2 to 4 having a diameter (d_2) of 39.1 mm were produced using the compositions shown in Table 1, and the core of Comparative Examples 1 to 7 were produced using the compositions shown in Table 2. The hardness at a surface and amounts of deformation of the respective cores were measured by the methods described above. The results of measurement for the core of Examples 1 to 4 are shown in Table 4, and those for Comparative Examples 1 to 7 are shown in Table 5.

Then, the cover of the golf ball of Example 1 was formed. By use of one of the cover compositions A to D shown in Table 3, the cover was formed on the core by injection molding. As a result, a three-piece golf ball having a diameter of 42.76 mm was produced. Repeating these steps, the three-piece golf balls of Examples 2 to 4 and Comparative Examples 1 to 7 were produced. The shore D hardness of cover, resilience, flight performance, controllability, and shot feeling of the respective golf balls were measured and evaluated by the methods described above. The results of measurement and evaluation for the golf balls of Examples 1 to 4 are shown in Table 4, and those for Comparative Examples 1 to 7 are shown in Table 5.

TABLE 1

	Example	1	2	3	4
Center	Butadiene rubber	100	100	100	100
	Zinc Acrylate	24	27	30	33
	Zinc oxide	6.77	55	42	33
	D P D S	0.4	0.4	0.4	1.0
	Dicumyl peroxide	1.4	1.4	1.4	0.7
	Vulcanization Temp.(° C.) × Time(min)	152 × 24	152 × 24	152 × 24	152 × 24
Outer shell	Butadiene rubber	100	100	100	100
	Zinc acrylate	30	30	30	30
	Zinc oxide	20	20	20	20
	D P D S	0.4	0.4	0.4	0.4
	Dicumyl peroxide	2.0	2.0	2.0	2.0
	Tungsten	13	13	13	13
	Vulcanization Temp.(° C.) × Time(min)	157 × 20	157 × 20	152 × 20	154 × 20
Cover		A	A	B	D

TABLE 2

	Comparative Example	1	2	3	4	5	6	7
Center	Butadiene rubber	100	100	100	100	100	100	100
	Zinc acrylate	27	28	27	30	27	32	27
	Zinc oxide	5.5	20	5.5	4.2	5.5	3.4	5.5
	DPDS	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Tungsten	—	16	—	—	—	—	—
	Dicumyl peroxide	1.4	1.4	1.4	1.4	1.4	1.4	1.4
	Vulcanization Temp (° C.) × Time (min)	152 × 24	152 × 24	140 × 22 168 × 6	152 × 24	152 × 24	152 × 24	157 × 20
Outer shell	Butadiene rubber	100	100	100	100	100	100	100
	Zinc acrylate	30	30	30	30	30	30	30
	Zinc oxide	20	5	20	20	20	20	20
	DPDS	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Dicumyl peroxide	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Tungsten	13	—	13	13	13	13	13
	Vulcanization Temp (° C.) × Time (min)	157 × 20	152 × 20	152 × 20	146 × 20	154 × 20	149 × 20	157 × 20
Cover		A	A	A	A	C	A	A

*In Comparative Example 3, the vulcanization was conducted at 140° C. for 22 minutes, and after that, at 160° C. for 6 minutes.

TABLE 3

	Cover composition	A	B	C	D
Ionomer	Surlyn8945	—	—	—	25
	Surlyn9945	—	20	—	25
	Surlyn AD8542	20	30	—	—
	Himilan1706	30	—	—	—
	Himilan1555	30	25	—	—
	Himilan1557	—	—	30	—
	Himilan1707	—	—	20	—
	Himilan1855	—	—	50	—
Elastomer	Epofriend A1010	8	10	—	15
	Septon HG252	—	—	—	35
	Pebax2533	12	15	—	—
Shore D hardness		58	55	63	51

As a base rubber for an center and an outer shell, BR11 (cis1,4-polybutadiene having 96% of cis1,4 bonds, a product of Nippon Synthetic Rubber Co., Ltd.) was used. In Tables 1 and 2, the term "DPDS" means diphyenyl sulfide, a product of Sumitomo Seika Co., Ltd.

As an ionomer for the cover, used were Himilan® 1707 (an ionomer resin of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Himilan® 1706 (an ionomer of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Himilan® 1555 (an ionomer of a sodium ion-neutralized ethylene-methacrylic acid copolymer), Himilan® 1557 (an ionomer resin of a zinc ion-neutralized ethylene-methacrylic acid copolymer), Surlyn® 8945 (an ionomer resin of a sodium ion neutralized ethylene-methacrylic acid copolymer), Surlyn® 9945 (an ionomer resin of a zinc ion neutralized ethylene-methacrylic acid copolymer), and Surlyn® 8542 (an ionomer resin of a magnesium ion neutralized ethylene-methacrylic acid copolymer). As a thermoplastic elastomer, used were Epofriend A1010 (a product of Daicel Chemical Industries Co., Ltd.), Septon HG252 (styrene elastomer, a product of Kuraray Co., Ltd.), and Pebax 2533 (polyamide elastomer, a product of ELF-ATOCHEM). Epofriend A1010 is a styrene elastomer which has polystyrene blocks as hard segment (referred to as "S") and polybutadiene block as soft segment (referred to as "B") and they are linked in the form of S-B-S and epoxidized.

TABLE 4

Example			1	2	3	4
Center	JIS-C hardness	Center point (X)	60	62	63	63
		5 mm	70	72	73	72
		10 mm	75	77	80	77
		15 mm	76	78	81	78
		Surface (Y)	75	76	79	77
	Y-X		15	14	16	13
	Diameter (d_1)		28	32	35	30
	Specific gravity (a)		1.05	1.05	1.05	1.05
	Deformation amount (p)		4.35	4.05	3.75	3.95
Outer shell	Specific gravity (b)		1.23	1.23	1.23	1.23
Core	Diameter (d_2)		39.1	39.1	39.1	39.1
	JIS-C hardness (Z)		87	87	83	85
	Deformation amount (q)		3.48	3.30	3.10	3.22
	Z-X		27	25	20	22
	b-a		0.18	0.18	0.18	0.18

TABLE 4-continued

Example			1	2	3	4
	p-q		0.87	0.75	0.65	0.73
Cover Properties	Shore D hardness		58	58	55	51
	Resilience		0.7633	0.7640	0.7622	0.7615
	Flight performance	Launch Angle	11.38	11.30	11.15	11.20
		Spin rate	2724	2755	2828	2835
		Carry	224.8	225.8	224.9	224.3
		Total	244.7	245.1	243.8	242.6
	Controllability	Spin rate	6542	6558	6632	6882
		Carry	35.1	34.9	34.8	34.7
		Run	3.9	4.1	4.5	4.1
	Shot feeling		◎	◎	◎	◎

TABLE 5

Comparative Example			1	2	3	4	5	6	7
Center	JIS-C hardness	Center point X	62	64	75	63	62	65	75
		5 mm	72	73	76	73	72	73	76
		10 mm	77	77	76	80	77	81	76
		15 mm	78	79	77	81	78	81	77
		Surface Y	76	77	76	79	76	80	76
	Y-X		14	13	1	16	14	15	1
	Diameter (d_1)		25	31	32	32	35	32	32
	Specific gravity (a)		1.05	1.25	1.05	1.05	1.05	1.05	1.05
	Deformation amount (p)		4.00	3.85	3.70	3.75	4.05	3.55	3.70
Outer shell	Specific gravity (b)		1.23	1.05	1.23	1.23	1.23	1.23	1.23
Core	Diameter (d_2)		39.1	39.1	39.1	39.1	39.1	39.1	39.1
	JIS-C hardness Z		87	83	83	77	85	80	87
	Deformation amount (q)		3.05	3.04	3.15	3.24	3.25	3.10	2.80
	p-q		0.95	0.81	0.55	0.51	0.80	0.45	0.90
	Z-X		25	19	8	14	23	15	12
	b-a		0.18	−0.20	0.18	0.18	0.18	0.18	0.18
Cover Properties	Shore D hardness		58	58	58	58	63	58	58
	Resilience		0.7553	0.7505	0.7650	0.7560	0.7735	0.7650	0.7675
	Flight perfor-mance	Launch Angle	11.12	11.10	10.97	10.83	11.39	10.98	11.01
		Spin rate	2788	2795	2892	2938	2724	2893	2897
		Carry	222.3	220.2	222.9	221.3	226.3	222.5	222.8
		Total	237.9	236.6	238.6	236.5	245.5	238.8	238.9
	Controll-ability	Spin rate	6561	6583	6591	6586	6132	6538	6530
		Carry	34.9	34.8	34.9	34.8	35.6	34.7	34.5
		Run	4.2	4.1	4.1	4.4	7.5	4.3	4.4
	Shot feeling		X	◎	Δ	◎	X	Δ	Δ

The evaluation on the shot feeling is as follows. From the comparison between Example 1 and Comparative Example 1, it is found that the shot feeling is impaired when the center has a diameter d_1) of 27 mm or smaller, even if the center point hardness (X), the center surface hardness (Y), and the core hardness (Z) are respectively the same with each other. From the results of Comparative Examples 3 and 7, it is found that the shot feeling is impaired when the center point hardness (X) is excessively large and (Y−X) is smaller than 8, even if the center hardness (Y), the core surface hardness (Z), and the cover hardness D are not excessively large. From the comparison between Example 3 and Comparative Example 5, it is found that the shot feeling is impaired when the cover hardness D is larger than 60, even if (Y−X), the core surface hardness (Z), and the center diameter d_1) are respectively the same with each other.

The evaluation on the flight distance is as follows. From the results of Comparative Examples 3 and 7, it is found that when (Y−X) is less than 8, the spin rate is too high, thereby causing to shorten a flight distance, and the shot feeling is impaired. From the result of Comparative Example 3, it is found that when (Z−X) is small, the launch angle becomes small, and the flight distance is further shortened. However, the golf balls of Comparative Examples 3 and 7 have sufficient spin to stop quickly with a short run on the green when hit by an iron at an approach shot (i.e. good controllability).

The evaluation on the flight performance are as follows. From the result of Comparative Example 4, it is found that when the core surface hardness (Z) is less than 80, the golf ball has poor resilience and has too high spin to attain a long flight distance, even if (Y−X) is 8 or larger and (Z−X) is 10 or larger. From the result of Comparative Example 2, it is found that when the specific gravity (a) is larger than the specific gravity (b) (i.e. a>b), a long flight distance cannot be attained, notwithstanding appropriate launch angle and spin, because the relationship of the specific gravity (i.e. a>b) cause the resilience of the golf ball to decrease. From the result of Comparative Example 6, it is found that when (p−q) is smaller, the launch angle becomes lower and the spin rate

becomes higher, resulting in shorter flight distance. However, the golf balls of Comparative Examples 2, 4, and 6 have sufficient high spin to stop quickly with a short run on the green when hit by an iron at an approach shot (i.e. good controllability).

From the result of Comparative Example 5, it is found that when the cover hardness D is larger than 60, the golf ball does not have enough spin to stop quickly on a green at an approach shot (i.e. poor controllability).

As seen in Table 4, the golf balls of Examples 1 to 4 satisfy the following requirements of the present invention: the center diameter (d_1) is in the range of 27 to 37 mm; the specific gravity (a) is smaller than the specific gravity (b); (Y−X) is 8 or larger; the core hardness (Z) is 80 or larger; (p−q) is 0.5 or larger; and a Shore D hardness of the cover is less than 60. The golf balls of Examples 1 to 4 attained a long flight distance while exhibiting a excellent controllability, and furthermore provided a excellent shot feeling.

What is claimed is:

1. A three-piece golf ball comprising:

a core having diameter of 38 to 41 mm consisting of

a center which has a diameter of 27 to 37 mm, a specific gravity (a)

wherein the specific gravity (a) ranges from 1.0 to 1.2, a JIS-C hardness (X) at the center point thereof, a JIS-C hardness (Y) at a surface thereof satisfying the equation: $8 \leqq (Y-X) \leqq 25$, and a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto, and

an outer shell placed-on the center, and having a specific gravity (b) satisfying the equation: $0.1 \leqq (b-a) \leqq 0.3$; and

a cover placed on the core having a Shore D hardness in the range of 50 to 60,

wherein a JIS-C hardness (Z) at a surface of the core is in the range of 82 to 90, the JIS-C hardness (Z) satisfying the equation: $10 \leqq (Z-X) \leqq 35$, and a deformation amount (q) of the core satisfies the equation: $0.5 \leqq (p-q) < 1.5$, when applying a load from 10 kgf as an initial load to 130 kgf as a final load to the core.

2. A three-piece golf ball comprising:

a core having diameter of 38 to 41 mm consisting of a center which has a diameter of 27 to 37 mm, a specific gravity (a)

wherein the specific gravity (a) ranges from 1.0 to 1.2, a JIS-C hardness (X) at the center point thereof, a JIS-C hardness (Y) at a surface thereof satisfying the equation: $8 \leqq (Y-X) \leqq 25$, and a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto, and

an outer shell placed on the center, and having a specific gravity (b) satisfying the equation: $0.1 \leqq (b-a) \leqq 0.3$; and

a cover placed on the core having a Shore D hardness in the range of 50 to 60 exclusive,

wherein a JIS-C hardness (Z) at a surface of the core is 85 or larger, the JIS-C hardness (Z) satisfying the equation: $22 \leqq (Z-X) \leqq 35$, and a deformation amount (q) of the core satisfies the equation: $0.5 < (p-q) < 1.5$, when applying a load from 10 kgf as an initial load to 130 kgf as a final load to the core.

3. A three-piece golf ball comprising:

a core having diameter of 38 to 41 mm consisting of:

a center having a diameter of 27 to 37 mm, a specific gravity (a), a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto, and wherein the deformation amount (p) ranges from 3.0 to 5.0 mm, a JIS-C hardness (Y) at a surface thereto, which ranges from 70 to 90, and a JIS-C hardness (X) at the center point thereof in the range of 55 to 75 satisfying the equation: $10 \leqq (Y-X) \leqq 25$,

an outer shell placed on the center, and having a specific gravity (b) which is larger than the specific gravity (a) wherein the specific gravity (a) ranges from 1.0 to 1.2 and the specific gravity (b) ranges from 1.10 to 1.30, and (b−a) is such that $0.1 \leqq (b-a) \leqq 0.3$; and

a cover placed on the core having a Shore D hardness of less than 60,

wherein a JIS-C hardness (Z) at a surface of the core is 82 to 95, and (Z−X) ranges from 10 to 35, and a deformation amount (q) of the core satisfies the equation: $0.5 \leqq (p-q) \leqq 1.5$, when applying a load from 10 kgf as an initial load to 130 kgf as a final load to the core.

4. A three-piece golf ball comprising:

a core having diameter of 38 to 41 mm consisting of:

a center having a diameter of 27 to 37 mm, a specific gravity (a), a deformation amount (p) of the center when applying a load from 10 kgf as an initial load to 130 kgf as a final load thereto, and wherein the deformation amount (p) ranges from 3.0 to 5.0 mm, a JIS-C hardness (Y) at a surface thereof, which ranges from 70 to 90, and a JIS-C hardness (X) at the center point thereof in the range of 55 to 75 satisfying the equation: $10 \leqq (Y-X) \leqq 25$,

an outer shell placed on the center, and having a specific gravity (b) which is larger than the specific gravity (a) wherein the specific gravity (a) ranges from 1.0to 1.2 and the specific gravity (b) ranges from 1.10 to 1.30, and (b−a) is such that $0 \leqq (b-a) \leqq 0.3$; and

a cover placed on the core having a Shore D hardness of less than 60,

wherein a JIS-C hardness (Z) at a surface of the core is 85 or larger, and (Z−X) ranges from 22 to 35, and a deformation amount (q) of the core satisfies the equation: $0.5 \leqq (p-q) \leqq 1.5$, when applying a load from 10 kgf as an initial load to 130 kgf as a final load to the core.

5. A three-piece golf ball according to claims 3 or 4, wherein the specific gravity (a) and the specific gravity (b) satisfy the equation $(b-a) \geqq 0.1$.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,390,935 B1
DATED : May 21, 2002
INVENTOR(S) : Kazushige Sugimoto

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 15,
Line 33, please change "placed-on" to -- placed on --
Line 37, please insert "exclusive" after "60,"
Line 42, please change "$0.5 \leq (p\text{-}q) < 1.5$" to -- $0.5 \leq (p\text{-}q) \leq 1.5$ --

Column 16,
Line 4, please change "$0.5 \leq (p\text{-}q) < 1.5$" to -- $0.5 \leq (p\text{-}q) \leq 1.5$ --
Line 45, please change "1.0to" to -- 1.0 to --
Line 47, please change "$0 \leq (b\text{-}a) \leq 0.3$" to -- $0 < (b\text{-}a) \leq 0.3$ --

Signed and Sealed this

Twenty-first Day of October, 2003

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

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(12) **United States Patent**
Yokota

(10) **Patent No.: US 6,386,993 B1**
(45) **Date of Patent: *May 14, 2002**

(54) **TWO-PIECE SOLID GOLF BALL**

(75) Inventor: **Masatoshi Yokota**, Akashi (JP)

(73) Assignee: **Sumitomo Rubber Industries, Ltd.**, Hyogo-Ken (JP)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(52) **U.S. Cl.** **473/373**; 473/373; 473/374; 473/375; 473/377

(58) **Field of Search** 473/373, 374, 473/375, 377

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(57) **ABSTRACT**

The present invention provides a two-piece solid golf ball having excellent flight performance and good shot feel when hit by a driver, and excellent controllability when hit by an iron club. The present invention relates to a two-piece solid golf comprising a core, and a cover formed on the core, wherein the core has a JIS-C center hardness of not more than 60, a JIS-C surface hardness of 70 to 95, a difference between the center hardness and surface hardness of 20 to 40 and a deformation amount of 2.6 to 3.5 mm when applying from an initial load of 10 kgf to a final load of 130 kgf, and the cover has a Shore D hardness of not more than 60 and a thickness of 1.2 to 2.0 mm.

10 Claims, No Drawings

TWO-PIECE SOLID GOLF BALL

FIELD OF THE INVENTION

The present invention relates to a two-piece solid golf ball. More particularly, it relates to a two-piece solid golf ball having excellent flight performance and good shot feel when hit by a driver, and excellent controllability when hit by an iron club.

BACKGROUND OF THE INVENTION

Many types of golf balls are commercially selling, but two-piece solid golf balls and thread wound golf balls are generally used for round games. The two-piece solid golf ball, when compared with the thread wound golf ball, has better durability and better flight performance because of larger initial velocity when hitting and longer flight distance. The two piece solid golf ball is generally approved of or employed by many golfers, especially amateur golfers. On the other hand, the two-piece solid golf ball has poor shot feel at the time of hitting and poor controllability at approach shot because of spin rate.

In the past, golf balls having good shot feel and controllability have been proposed in, for example, Japanese Patent Kokai Publication No. 98949/1994, Japanese Patent Kokai Publication No. 154357/1994, Japanese Patent Kokai Publication No. 289661/1995, Japanese Patent Kokai Publication No. 194732/1995, Japanese Patent Kokai Publication No. 239607/1997. These golf balls adopt a two-piece structure in which hardness distribution from a center point to a surface of a core is controlled to a proper range, to obtain shot feel and controllability similar to the thread wound golf ball.

For example, Japanese Patent Kokai Publication Nos. 98949/1994 and 154357/1994 suggest a two-piece golf ball in which hardness distribution of the core is controlled so as to increase the hardness in order, a center point, 5 to 10 mm from the center point, 15 mm from the center point and a surface. However, since a cover, which has a flexural modulus of 3,000 to 4,500 kgf/cm^2, is hard, shot feel and controllability of the golf ball are poor.

Japanese Patent Kokai Publication No. 289661/1995 suggests a two-piece golf ball, of which a core has a JIS-C surface hardness of 55 to 75, a JIS-C hardness of cross section other than the surface of 65 to 85 and a variance of hardness over the cross section of not more than 5. The surface hardness is smaller than the hardness of the cross section by not less than 5. However, since the surface of the core is soft in the golf ball, shot feel is poor.

Japanese Patent Kokai Publication No. 194782/1995 suggests a two-piece golf ball, of which a core has a JIS-C center hardness of 40 to 57, a JIS-C surface hardness of 70 to 95, and difference between the center hardness and the surface hardness of 20 to 40. However, since the cover, which has a thickness of 1.4 to 2.7 mm, is thick and hard in the golf ball, shot feel and controllability are poor.

Japanese Patent Kokai Publication No. 239067/1997 suggests a two-piece golf ball, of which a core has a JIS-C surface hardness of not more than 85, and hardness distribution that a center hardness is smaller w than the surface hardness by 8 to 20 and a hardness at the portion of not more than 5 mm from the surface is smaller than the surface hardness by not more than 8. However, since the difference between the center hardness and the surface hardness is small in the golf ball, shot feel is poor, and fight performance is not sufficient.

It is required to solve the above problem and provide a two-piece golf ball having better flight performance, better shot feel and better controllability. Therefore, it is required to improve such physical properties further.

OBJECTS OF THE INVENTION

A main object of the present invention is to provide a two-piece solid golf ball having excellent flight performance and good shot feel when hit by a driver, and excellent controllability when hit by an iron club.

According to the present invention, the object described above has been accomplished by adjusting a center hardness, surface hardness, a difference between the center hardness and the surface hardness and a deformation amount when applying from an initial load of 10 kgf to a final load of 130 kgf of the core, and a hardness and thickness of the cover to a specified range, thereby providing a two-piece solid golf ball having excellent flight performance and good shot feel when hit by a driver, and excellent controllability when hit by an iron club.

SUMMARY OF THE INVENTION

The present invention provides a two-piece solid golf ball comprising a core, and a cover formed on the core, wherein the core has a JIS-C center hardness of not more than 60, a JIS-C surface hardness of 70 to 95, a difference between the center hardness and surface hardness of 20 to 40 and a deformation amount of 2.6 to 3.5 mm when applying from an initial load of 10 kgf to a final load of 130 kgf, and the cover has a Shore D hardness of not more than 60 and a thickness of 1.2 to 2.0 mm.

DETAILED DESCRIPTION OF THE INVENTION

The two-piece solid golf ball of the present invention comprises a core, and a cover formed on the core. The core is obtained by press molding and vulcanizing a rubber composition using a method and condition which have been conventionally used for preparing the core of solid golf balls. The rubber composition contains a base rubber, a co-crosslinking agent, an organic peroxide, and optionally an organic sulfide compound, a filler, an antioxidant and the like.

The base rubber used for the core of the present invention may be natural rubber and/or synthetic rubber, which has been conventionally used for solid golf balls. Preferred is high-cis polybutadiene rubber containing not less than 40%, preferably not less than 80% of a cis-1, 4 bond. The high-cis polybutadiene rubber may be mixed with natural rubber, polyisoprene rubber, styrene-butadiene rubber, ethylene-propylene-diene rubber. (EPDM) and the like.

The co-crosslinking agent can be a metal salt of α, β-unsaturated carboxylic acid, including mono or divalent metal salts, such as zinc or magnesium salts of α,β-unsaturated carboxylic acids having 3 to 8 carbon atoms (e.g. acrylic acid, methacrylic acid, etc.). Preferred co-crosslinking agent is zinc diacrylate because it imparts high rebound characteristics to the resulting golf ball. An amount of the metal salt of the unsaturated carboxylic acid in the rubber composition may be from 20 to 40 parts by weight, preferably from 22 to 38 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the metal salt of the unsaturated carboxylic acid is smaller than 20 parts by weight, the core is too soft, and rebound characteristics are degraded to reduce flight distance. On the

other hand, when the amount of the metal salt of the unsaturated carboxylic acid is larger than 40 parts by weight, the core is too hard, and shot feel is poor.

The organic peroxide includes, for example, dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, 2,5-dimethyl-2,5-di(t-butylperoxy) hexane, di-t-butyl peroxide and the like. Preferred organic peroxide is dicumyl peroxide. An amount of the organic peroxide may be from 0.3 to 5.0 parts by weight, preferably 0.5 to 3.0 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the organic peroxide is smaller than 0.3 parts by weight, the core is too soft and rebound characteristics are degraded to reduce flight distance. On the other hand, when the amount of the organic peroxide is larger than 5.0 parts by weight, the core is too hard, and shot feel is poor.

The rubber composition for the core of the golf ball of the present invention may optionally contain an organic sulfide compound in addition to the above components. The organic sulfide compound includes polysulfides having 2 to 4 sulfur atoms, such as diphenyl polysulfide, dibenzyl polysulfide, dibenzoyl polysulfide, dibenzothiazoyl polysulfide, dithiobenzoyl polysulfide and the like. Preferred organic sulfide compound is diphenyl disulfide, in view of rebound characteristics. An amount of the organic sulfide compound may be from 0.1 to 3.0 parts by weight, preferably from 0.3 to 2.0 parts by weight, based on 100 parts by weight of the base rubber. When the amount of the organic sulfide compound is smaller than 0.1 parts by weight, the technical effects of the organic sulfide compound do not sufficiently exhibit. On the other hand, when the amount of the organic sulfide compound is larger than 3.0 parts by weight, the technical effects are not improved more. By using the organic sulfide compound in the rubber composition for the core, the crosslinkage of the rubber by co-crosslinking agent shows high density, and thus rebound characteristics are improved.

The rubber composition for the core of the golf ball of the present invention can contain other components, which have been conventionally used for preparing the core of solid golf balls, such as inorganic filler (such as zinc oxide, barium sulfate, calcium carbonate and the like), high specific gravity metal powder filler (such as tungsten powder, molybdenum powder and the like), antioxidant or peptizing agent. If used, an amount of the antioxidant is preferably 0.2 to 0.5parts by weight, based on 100 parts by weight of the base rubber.

The core is obtained by mixing the above rubber composition, and vulcanizing and press-molding it in a mold. The core of the golf ball of the present invention has a JIS-C center hardness of not more than 60, preferably 40 to 60 more preferably 50 to 59. When the center hardness of the core is more than 60, shot feel is hard and poor. The core of the golf ball of the present invention has a JIS-C surface hardness of 70 to 95, preferably 75 to 90, more preferably 78 to 87. When the surface hardness of the core is smaller than 70, rebound characteristics are degraded. On the other hand, when the surface hardness of the core is larger than 95, shot feel is hard and poor. The center hardness of the core is smaller than the surface hardness of the core, and the difference between the center hardness and surface hardness is 20 to 40, preferably 20 to 35, more preferably 20 to 30. When the difference is smaller than 20, launch angle is small to reduce flight distance. On the other hand, when the difference is larger than 40, shot feel is little and poor. The term "a center hardness of a core" as used herein refers to the hardness, which is obtained by cutting the core into two equal parts and then measuring a hardness at center point.

The core of the golf ball of the present invention has a deformation amount of 2.6 to 3.5 mm, preferably 2.8 to 3.4 mm when applying from an initial load of 10 kgf to a final load of 130 kgf on the core. When the deformation amount is smaller than 2.6 mm, the core is too hard and the shot feel of the resulting golf ball is poor. On the other hand, when the deformation amount is larger than 3.5 mm, the core is too soft and rebound characteristics are degraded to reduce flight distance.

Molding the core within the ranges described above can be conducted by adjusting the vulcanization condition. That is, it can be conducted by setting the vulcanization condition so that the degree of the vulcanization peaks from 5 to 20 minutes later, if the vulcanization is initiated at the time of clamping. The core having the above hardness and deformation amount can be typically obtained by vulcanizing and press-molding the rubber composition at 130 to 180° C. for 10 to 40 minutes. The core of the golf ball of the present invention has a diameter of 38.0 to 41.0 mm, preferably 38.5 to 40.5 mm. When the diameter of the core is smaller than 38.0 mm, the cover is too thick. Therefore, the technical effects of he core, such as rebound characteristics and the like, do not sufficiently exhibit. On the other hand, when the diameter is larger than 41.0 mm, the cover is too thin, and cut resistance is poor. A cover is then covered on the core.

The cover of the golf ball of the present invention has a Shore D hardness of not more than 60, preferably 50 to 60, more preferably 52 to 59. When the Shore D hardness is larger than 60, shot feel is hard and poor, and controllability at approach shot is poor. The cover has a thickness of 1.2 to 2.0 mm, preferably 1.3 to 1.9 mm. When the thickness is smaller than 1.2 mm, cut resistance is poor. On the other hand, the thickness is larger than 2.0 mm, rebound characteristics are degraded to reduce flight distance.

The material used for the cover of the present invention is not limited, as long as the above physical properties are imparted to it, but the material which has been conventionally used for solid golf ball cover can be used. Preferred material is thermoplastic resin. Examples of thermoplastic resins include ionomer resin, polyethylene resin, polyurethane resin, 1,2-polybutadiene, styrene-butadiene copolymer and the like, or the mixture thereof. The ionomer resin used in the present invention includes ethylene-(meth) acrylic acid copolymer, of which a portion of carboxylic acid groups is neutralized with metal ion. The metal ion which neutralizes a portion of carboxylic acid groups of the copolymer includes alkaline metal ion, such as sodium ion, potassium ion, lithium ion and the like; divalent metal ion, such as zinc ion, calcium ion, magnesium ion and the like; trivalent metal ion, such as aluminum ion, neodymium ion and the like; and the mixture thereof. Preferred are sodium ion, zinc ion, lithium ion and the like, in view of rebound characteristics, durability and the like. The ionomer resin is not limited, but examples thereof will be shown by a trade name thereof. Examples of the ionomer resin, which is commercially available from Mitsui Du Pont Polychemical Co., Ltd., include Hi-milan 1555, Hi-milan 1557, Hi-milan 1605, Hi-milan 1652 Hi-milan 1705, Hi-milan 1706, Hi-milan 1707, Hi-milan 1855 Hi-milan 1856 and the like. Examples of the ionomer resin, which is commercially available from Du Pont U.S.A., include Surlyn AM7317, Surlyn AM7318, Surlyn 8320 and the like. Examples of the ionomer resin, which is commercially available from Exxon Chemical Co., include Iotek 7010, Iotek 8000 and the like. Examples of polyethylene resins include UJ960, which is commercially available from Mitsubishi Chemical Co., Ltd. and the like. Examples of polyamide resins include Diamide

E40-S3, E47-S3, and E55-S3, which are commercially available from Daicel Hulls Co., Ltd., and Pebax 5533SN00, 4033SN00 and 2533SN00, which are commercially available from Atochem Co. and the like. Examples of polyurethane include Elastoran ET880 and ET890, which are commercially available from Takeda Verdishe Co., Ltd., Pandex T-8180, which is commercially available from Dainippon Ink Chemical Co., Ltd. and the like.

The cover used in the present invention may optionally contain fillers (such as barium sulfate, calcium carbonate, etc.), coloring agents (such as titanium dioxide, etc.), and the other additives such as a dispersant, an antioxidant, a UV absorber, a photostabilizer and a fluorescent agent or a fluorescent brightener, etc., in addition to the resin component, as long as the addition of the additives does not deteriorate the desired performance of the golf ball cover. An amount of the pigment is preferably 0.1 to 5 parts by weight, based on 100 parts by weight of the resin component for the cover.

A method of covering the core with the cover is not specifically limited, but may be a well-known method, which has been conventionally used for forming golf ball cover. For example, there can be used a method comprising molding the cover composition into a semi-spherical half-shell in advance, covering the solid core with the two half-shells, followed by pressure molding, or a method comprising injection molding the cover composition directly on the core to cover it. At the time of cover molding, many depressions called "dimples" may be optionally formed on the surface of the golf ball. Furthermore, paint finishing or marking stamp may be optionally provided after cover molding for serving commercial sell. The two-piece solid golf ball of the present invention is formed, so that it has a diameter of not less than 42.67 mm and a weight of not more than 45.93 g, according to the PGA rule.

EXAMPLES

The following Examples and Comparative Examples further illustrate the present invention in detail but are not to be construed to limit the scope of the present invention.

Examples 1 to 5 and Comparative Examples 1 to 5

Production of core

The rubber compositions for the core shown in Table 1 (Example)) and Table 2 (Comparative Example) were mixed with a mixing roll, and then vulcanized by press-molding at the vulcanization condition shown in the same Table to obtain spherical cores. The diameter, hardness distribution and deformation amount of the resulting core were measured. The results are shown in Table 4 (Example) and Table 2 (Comparative Example). The test methods are described later.

TABLE 1

(parts by weight)

	Example No.				
Core composition	1	2	3	4	5
BR18 *1	100	100	100	100	100
Zinc diacrylate	30	33	36	33	33
Zinc oxide	15.2	14.1	13.0	17.2	11.5
Antioxidant *2	0.5	0.5	0.5	0.5	0.5
Dicumyl peroxide	2.0	2.0	2.0	2.0	2.0

TABLE 1-continued

(parts by weight)

	Example No.				
Core composition	1	2	3	4	5
Diphenyl disulfide	0.5	0.5	0.5	0.5	0.5
Vulcanization condition	*a	*a	*a	*a	*a

TABLE 2

(parts by weight)

	Comparative Example No.				
Core composition	1	2	3	4	5
BR18 *1	100	100	100	100	100
Zinc diacrylate	24	30	36	33	33
Zinc oxide	17.5	15.2	13.0	14.1	18.7
Antioxidant *2	0.5	0.5	0.5	0.5	0.5
Dicumyl peroxide	2.0	2.0	2.0	2.0	2.0
Diphenyl disulfide	0.5	0.5	0.5	0.5	0.5
Vulcanization condition	*a	*b	*b	*a	*a

*1: High-cis Polybutadiene rubber (trade name "BR18") available from JSR Co., Ltd.
*2: Antioxidant (trade name "Yoshinox 425") from Yoshitomi Pharmaceutical Ind., Ltd.
(Vulcanization condition)
*a: at 170° C. for 20 minutes
*b: at 150° C. for 35 minutes

Preparation of cover compositions

The formulation materials shown in Table 3 were mixed using a kneading type twin-screw extruder to obtain pelletized cover compositions. The extrusion condition was,

a screw diameter of 45 mm,

a screw speed of 200 rpm, and

a screw L/D of 35.

The formulation materials were heated at 200 to 260° C. at the die position of the extruder. The Shore D hardness of the resulting cover compositions were shown in Table 4 and Table 5. The test methods are described later.

TABLE 3

(parts by weight)

Cover composition	A	B
Hi-milan 1555 *3	5	—
Hi-milan 1605 *4	—	50
Hi-milan 1706 *5	—	50
Hi-milan 1855 *6	95	—
Titanium dioxide	2	2
Barium sulfate	2	2

*3: Hi-milan 1555 (trade name), ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with sodium ion, manufactured by Mitsui DuPont Polychemical Co., Ltd.
*4: Hi-milan 1605 (trade name), ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with sodium ion, manufactured by Mitsui DuPont Polychemical Co., Ltd.
*5: Hi-milan 1706 (trade name), ethylene-methacrylic acid copolymer ionomer resin obtained by neutralizing with zinc ion, manufactured by Mitsui DuPont Polychemical Co., Ltd.
*6: Hi-milan 1855 (trade name), ethylene-methacrylic acid-isobutyl acrylate terpolymer ionomer resin obtained by neutralizing with zinc ion, manufactured by Mitsui DuPont Polychemical Co., Ltd.

Production of golf ball

The cover compositions shown in Table 4 (Example) and Table 5 (Comparative Example) were covered on the resulting core by injection molding. Then, deflashing, surface pretreatment for painting, paint and the like, which are

generally done on the surface of a golf ball, were conducted on the surface to produce a golf ball having a weight of 45.4 g and a diameter of 42.7 mm. With respect to the resulting golf balls, deformation amount, flight distance, spin amount (when hit by a sand wedge), shot feel at the time of hitting (by a driver) and controllability at approach shot (by a sand wedge) were measured or evaluated. The results are shown in Table 4 (Example) and Table 5 (Comparative Example). The test methods are as follows.

(Test method)

(1) Deformation amount

The deformation amount was determined by applying an initial load of 10 kg to a final load of 130 kg on the core or golf ball.

(2) Shore D hardness of cover

The Shore D hardness was determined according to ASTM D-2240, using a sample of a stack of the three or more sheets which were obtained by heat and press molding the each cover composition into a sheet having a thickness of about 2 mm and storing at 23° C. for 2 weeks.

(3) Flight distance

A No. 1 wood club (a driver) was mounted to a swing robot manufactured by True Temper Co. and the resulting golf ball was hit at a head speed of 45 m/second, flight distance to the firstly dropping point on the ground (carry) was measured.

(4) Shot feel and controllability

The shot feel of the golf ball is evaluated by 10 professional golfers according to a practical hitting test using a driver (a No. 1 wood club). The controllability of the golf ball is evaluated by 10 professional golfers according to a practical hitting test at 30 yards approach shot using a sand wedge. The evaluation criteria are as follows.

(Evaluation criteria):

o: Not less than 8 out of 10 golfers felt that the golf ball has good shot feel and good controllability.

Δ: From 4 to 7 out of 10 golfers felt that the golf ball has good shot feel and good controllability.

X: Not more than 3 out of 10 golfers felt that the golf ball has good shot feel and good controllability.

TABLE 4

Test item	Example No. 1	2	3	4	5
(Core)					
Diameter (mm)	39.6	39.6	39.6	39.0	40.2
JIS-C hardness					
Center point (a)	57	58	59	58	57
Surface (b)	81	83	85	80	85
Difference (b) − (a)	24	25	26	22	28
Deformation amount (mm)	3.4	3.1	2.8	3.0	3.2
(Cover)					
Composition	A	A	A	A	A
Shore D hardness	58	58	58	58	58
Thickness (mm)	1.6	1.6	1.6	1.9	1.3
(Ball)					
Deformation amount (mm)	3.2	2.9	2.6	2.7	3.1
Carry (yard)	253	254	256	253	256
Spin amount (rpm)	6880	6950	7020	6910	6960
Shot feel	O	O	O	O	O
Controllability	O	O	O	O	O

TABLE 5

Test item	Comparative Example No. 1	2	3	4	5
(Core)					
Diameter (mm)	39.6	39.6	39.6	39.6	38.2
JIS-C hardness					
Center point (a)	55	68	72	58	62
Surface (b)	79	76	81	83	80
Difference (b) − (a)	24	8	9	25	18
Deformation amount (mm)	4.2	3.3	2.5	3.1	2.9
Cover)					
Composition	A	A	A	B	A
Shore D hardness	58	58	58	69	58
Thickness (mm)	1.6	1.6	1.6	1.6	2.3
(Ball)					
Deformation amount (mm)	3.8	3.1	2.3	2.7	2.5
Carry (yard)	248	252	251	254	250
Spin amount (rpm)	6640	6890	7010	6950	6810
Shot feel	X	X	X	X	X
Controllability	X	Δ	Δ	X	Δ

As is apparent from the comparison of the physical properties of the golf balls of Examples 1 to 5 shown in Table 4 with those of the golf balls of Comparative Examples 1 to 5 shown in Table 5, the golf ball of the present invention of Examples. 1 to 6 have better shot feel and controllability than the golf ball of Comparative Examples 1 to 5, while keeping excellent flight distance.

On the other hand, the golf ball of Comparative Example 1 has larger deformation amount of the core, and thus the core is too soft. Therefore, rebound characteristics are degraded to reduce flight distance, and shot feel and controllability are poor. The golf ball of Comparative Examples 2 has higher center hardness of the core, and thus shot feel of the resulting golf ball is poor; difference between center hardness and surface hardness of the core is smaller, and thus launch angle of the resulting golf ball is small to reduce flight distance.

The golf ball of Comparative Example 3 has higher center hardness of the core, and thus shot feel of the resulting golf ball is poor. The golf ball has smaller difference between center hardness and surface hardness of the core, and thus launch angle of the resulting golf ball is small to reduce flight distance. The golf ball has larger deformation amount of the core, and thus the core is too hard and the shot feel of the resulting golf ball is poor.

The golf ball of Comparative Example 4 has larger cover hardness, and thus shot feel of the resulting golf ball is hard and poor, and controllability is poor. The golf ball of the Comparative Example 5 has higher center hardness of the core, and thus shot feel of the resulting golf ball is poor. The golf ball has smaller difference between center hardness and surface hardness of the core, and thus launch angle of the resulting golf ball is small to reduce flight distance. The golf ball has larger thickness of the cover, and thus rebound characteristics of the resulting golf ball are degraded to reduce flight distance, and shot feel and controllability are poor.

What is claimed is:

1. A two-piece golf ball, comprising:

a core, said core is formed from a rubber composition comprising:

20 to 40 parts by weight of a co-crosslinking agent,

0.5 to 3.0 parts by weight of an organic peroxide, and

0.1 to 5.0 parts by weight of an organic sulfide compound, based on 100 parts by weight of cis-1,4-polybutadiene containing not less than 40% of cis-1,4 bond content as a base rubber; and

a cover formed on the core,

wherein the core has a diameter of 38.5 to 40.5 mm, a JIS-C center hardness of not more than 60, a JIS-C surface hardness of 70 to 95, a difference between the center hardness and the surface of 20 to 40 and a deformation amount of 2.8 to 3.4 mm when applying from an initial load of 10 kgf to a final load of 130 kgf, and the cover has a Shore D hardness of not more than 60 and a thickness of 1.2 to 2.0 mm.

2. The two-piece solid golf ball according to claim 1, wherein the cover is formed from ionomer resin, polyolefin resin, polyamide resin, polyurethane resin, 1,2-polybutadiene, styrene-butadiene copolymer, or the mixture thereof.

3. The two-piece golf ball according to claim 1, wherein said co-crosslinking agent is a metal salt of an α,β-unsaturated carboxylic acid.

4. The two-piece golf ball according to claim 1, wherein said co-crosslinking agent is a zinc or magnesium salt of an α,β-unsaturated carboxylic acid having 3 to 8 carbon atoms.

5. The two-piece golf ball according to claim 1, wherein said co-crosslinking agent is zinc diacrylate.

6. The two-piece golf ball according to claim 1, wherein said organic peroxide is dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, 2,5-dimethyl-2,5-di(t-butylperoxy) hexane or di-t-butylperoxide.

7. The two-piece golf ball according to claim 1, wherein said organic peroxide is dicumyl peroxide.

8. The two-piece golf ball according to claim 1, wherein said organic sulfide compound is a polysulfide having 2 to 4 sulfur atoms.

9. The two-piece golf ball according to claim 1, wherein said organic sulfide compound is diphenyl polysulfide, dibenzyl polysulfide, dibenzoyl polysulfide, dibenzothiazoyl polysulfide or dithiobenzoyl polysulfide.

10. The two-piece golf ball according to claim 1, wherein said organic sulfide compound is diphenyl disulfide.

* * * * *

EXHIBIT 13

US005782707A

United States Patent [19]

Yamagishi et al.

[11] Patent Number: 5,782,707

[45] Date of Patent: Jul. 21, 1998

[54] **THREE-PIECE SOLID GOLF BALL**

[75] Inventors: **Hisashi Yamagishi; Hiroshi Higuchi**, both of Chichibu, Japan

[73] Assignee: **Bridgestone Sports Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **812,925**

[22] Filed: **Mar. 10, 1997**

[30] **Foreign Application Priority Data**

Mar. 11, 1996 [JP] Japan 8-082121

[51] **Int. Cl.**^{6} **A63B 37/06**; A63B 37/12; A63B 37/14

[52] **U.S. Cl.** **473/374**; 473/373

[58] **Field of Search** 473/373, 374, 473/378, 384

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Primary Examiner—George J. Marlo

Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas, PLLC

[57] **ABSTRACT**

The invention provides a three-piece solid golf ball featuring an increased flight distance on driver shots and improved control on approach shots. In a three-piece solid golf ball consisting of a solid core, an intermediate layer, and a cover, provided that hardness is measured by a JIS-C scale hardness meter, the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 8 to 20 degrees, the intermediate layer hardness is higher than the core surface hardness by at least 5 degrees, and the cover hardness is lower than the intermediate layer hardness by at least 5 degrees.

6 Claims, 2 Drawing Sheets

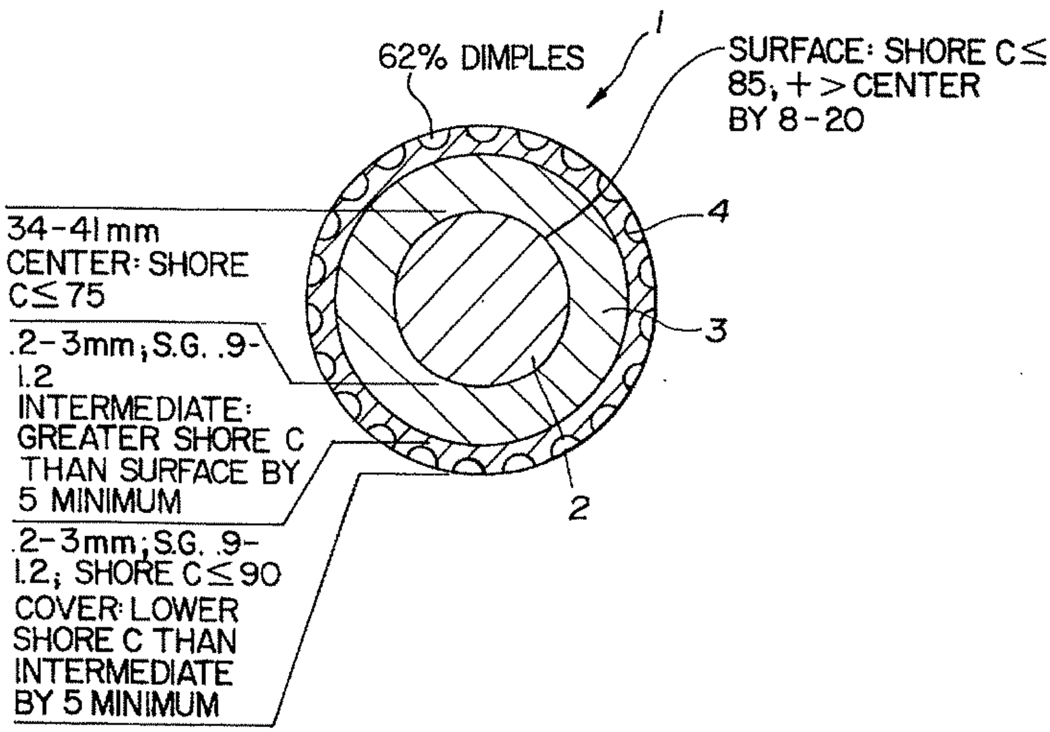


FIG.1

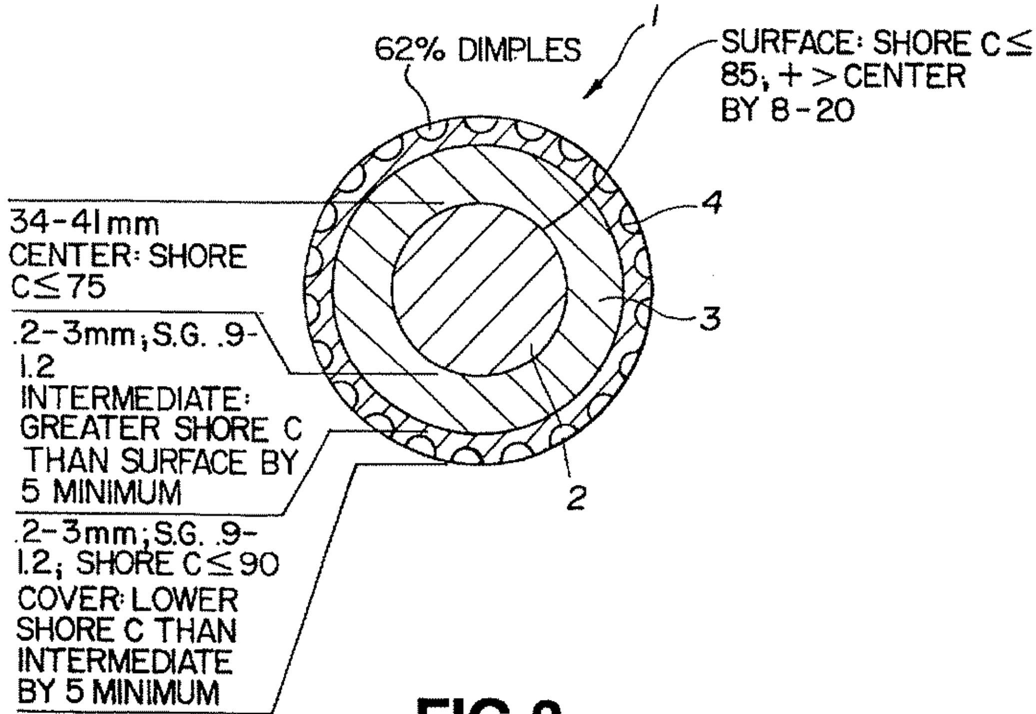

62% DIMPLES
1
SURFACE: SHORE C ≤ 85; + > CENTER BY 8-20
34-41mm CENTER: SHORE C ≤ 75
4
3
.2-3mm; S.G. .9-1.2 INTERMEDIATE: GREATER SHORE C THAN SURFACE BY 5 MINIMUM
2
.2-3mm; S.G. .9-1.2; SHORE C ≤ 90 COVER: LOWER SHORE C THAN INTERMEDIATE BY 5 MINIMUM

FIG.2

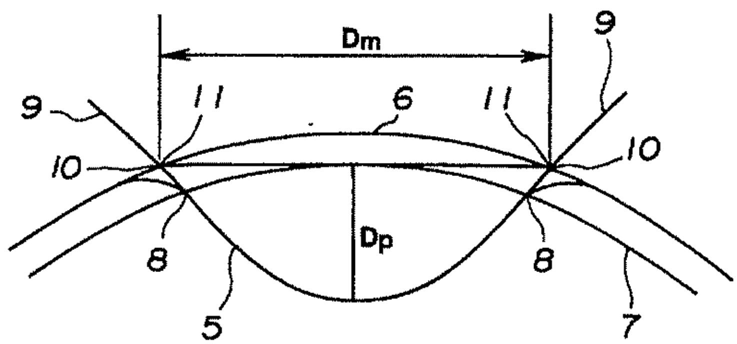

Dm
9
9
11
6
11
10
10
Dp
8
8
5
7

FIG.3

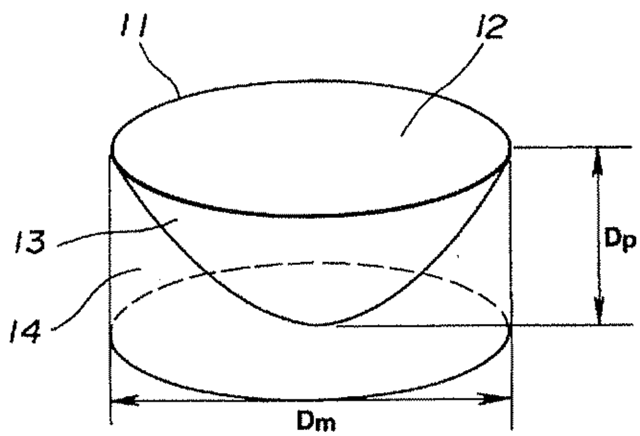
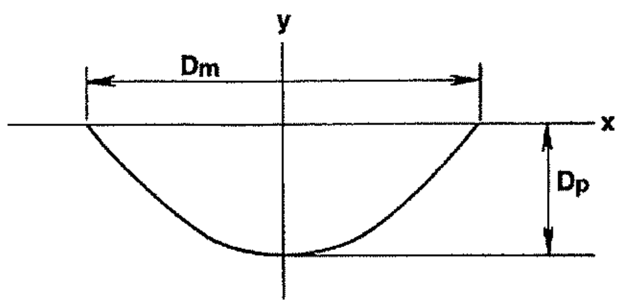


FIG.4



THREE-PIECE SOLID GOLF BALL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover and more particularly, to such a three-piece solid golf ball which features an increased flight distance on full shots with a driver and improved control on approach shots with No. 5 iron or sand wedge.

2. Prior Art

From the past, two-piece solid golf balls consisting of a solid core and a cover are used by many golfers because of their flight distance and durability features. In general, two-piece solid golf balls give hard hitting feel as compared with wound golf balls, and are inferior in feel and control due to quick separation from the club head. For this reason, many professional golfers and skilled amateur golfers who prefer feel and control use wound golf balls rather than two-piece solid golf balls. The wound golf balls are, however, inferior in carry and durability to the solid golf balls.

More particularly, when two-piece solid golf balls are subject to full shots with a club having a relatively large loft angle, the ball flight is mainly governed by the club loft rather than the ball itself so that spin acts on most balls to prevent the balls from too much rolling. However, on approach shots over a short distance of 30 to 50 yards, rolling or control substantially differs among balls. The major cause of this difference is not related to the basic structure of the ball, but to the cover material. Then some two-piece solid golf balls use a cover of a relatively soft material in order to improve control on approach shots, but at the sacrifice of flight distance.

Controllability is also needed on full shots with a driver. If a soft cover is used as a result of considering too much the purpose of improving spin properties upon control shots such as approach shots with No. 5 iron and sand wedge, hitting the ball with a driver, which falls within an increased deformation region, will impart too much spin so that the ball may fly too high, resulting in a rather reduced flight distance. On the other hand, if the spin rate is too low, there arises a problem that the ball on the descending course will prematurely drop, adversely affecting the ultimate flight distance too. As a consequence, an appropriate spin rate is still necessary upon driver shots.

Anyway, the prior art two-piece solid golf balls fail to fully meet the contradictory demands of players, the satisfactory flight performance that the ball acquires an adequate spin rate upon full shots with a driver and the ease of control that the ball acquires a high spin rate upon approach shots with No. 5 iron and sand wedge.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a three-piece solid golf ball which features an increased flight distance on full shots with a driver and improved control on approach shots with No. 5 iron or sand wedge.

Making extensive investigations on a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover, we have found that the above object is attained by optimizing the hardness distribution of the core, forming a hard intermediate layer between the core and the soft cover, and adjusting a percent dimple surface occupation. By virtue of the synergistic effect

of these factors, the resulting golf ball travels an increased flight distance on full shots with a driver and is well controllable on approach shots with No. 5 iron or sand wedge.

More specifically, we have found that the following advantages are obtained in a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover, when the solid core, intermediate layer, and cover each have a hardness as measured by a JIS-C scale hardness meter, the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 8 to 20 degrees, the intermediate layer hardness is higher than the core surface hardness by at least 5 degrees, and the cover hardness is lower than the intermediate layer hardness by at least 5 degrees. Upon deformation in an increased deformation region (associated with full shots with a driver), the presence of a hard intermediate layer between a soft deformable cover and a soft core ensuring soft feel is effective for reducing the energy loss by excessive deformation of the core and thereby enabling to form a structure of efficient restitution while maintaining the softness of the ball as a whole. Then the ball will travel an increased flight distance upon full shots with a driver. Although a soft cover is used, the ball gains an appropriate spin rate and is free of shortage of flight distance. At the same time, in a reduced deformation region (associated with approach shots), the ball gains an increased spin rate and is well controllable. Additionally, by adjusting dimples such that the percent surface occupation of dimples in the cover surface is at least 62% and an index (Dst) of overall dimple surface area is at least 4, and optimizing the dimple pattern, the flight properties (flight distance and flight-in-wind) of the golf ball are further enhanced. By virtue of the synergistic effect of these factors, the resulting golf ball covers an increased flight distance on full shots with a driver and is well controllable on approach shots with No. 5 iron or sand wedge, that is, satisfies the contradictory demands of players.

Therefore, according to the present invention, there is provided a three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover, having a plurality of dimples in the ball surface. Provided that the solid core at its surface and center, the intermediate layer, and the cover each have a hardness as measured by a JIS-C scale hardness meter, the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 8 to 20 degrees, the intermediate layer hardness is higher than the core surface hardness by at least 5 degrees, and the cover hardness is lower than the intermediate layer hardness by at least 5 degrees. The dimples occupy at least 62% of the ball surface.

In one preferred embodiment, the dimples in the ball surface total in number to 360 to 450 and include at least two types of dimples having different diameters. An index (Dst) of overall dimple surface area given by the following expression (1) is at least 4.

$$Dst = \frac{n \sum_{k-1}^{n} [(Dmk^2 + Dpk^2) x V_0 k x Nk]}{4R^2} \tag{1}$$

wherein R is a ball radius, n is the number of dimple types, Dmk is a diameter of dimples k, Dpk is a depth of dimples k, Nk is the number of dimples k wherein k=1, 2, 3, . . . n, and V_0 is the volume of the dimple space below a plane circumscribed by the dimple edge divided by the volume of a cylinder whose bottom is the plane and whose height is the maximum depth of the dimple from the bottom.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of a three-piece solid golf ball according to one embodiment of the invention.

FIG. 2 is a schematic cross-sectional view of a dimple illustrating how to calculate V_0.

FIG. 3 is a perspective view of the same dimple.

FIG. 4 is a cross-sectional view of the same dimple.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, a three-piece solid golf ball 1 according to the invention is illustrated as comprising a solid core 2 having an optimized hardness distribution, a hard intermediate layer 3, and a soft cover 4.

In the golf ball 1 of the invention, the hardness distribution of the solid core 2 is optimized. More particularly, the core 2 is formed to have a center hardness of up to 75 degrees, preferably 60 to 73 degrees, more preferably 63 to 69 degrees as measured by a JIS-C scale hardness meter. The core 2 is also formed to have a surface hardness of up to 85 degrees, preferably 70 to 83 degrees, more preferably 73 to 80 degrees. If the core center hardness exceeds 75 degrees and the surface hardness exceeds 85 degrees, the hitting feel becomes hard, contradicting the object of the invention. It is noted that the hardness referred to herein is JIS-C scale hardness unless otherwise stated.

The core is formed herein such that the surface hardness is higher than the center hardness by 8 to 20 degrees, preferably 10 to 18 degrees. A hardness difference of less than 8 degrees would result in a hard hitting feel provided that the ball hardness and the core surface hardness are fixed. A hardness difference of more than 20 degrees would fail to provide sufficient restitution provided that the ball hardness and the core surface hardness are fixed. The hardness distribution establishing such a hardness difference between the surface and the center of the core ensures that the core surface formed harder than the core center is effective for preventing excessive deformation of the core and efficiently converting distortion energy into reaction energy when the ball is deformed upon impact. Additionally, a pleasant feeling is obtainable from the core center softer than the core surface.

The hardness distribution of the solid core is not limited insofar as the core is formed such that the core surface is harder than the core center by 8 to 20 degrees. It is preferable from the standpoint of efficient energy transfer that the core is formed such that the core becomes gradually softer from its surface toward its center.

The solid core preferably has a diameter of 34 to 41 mm, especially 34.5 to 40 mm. No particular limit is imposed on the overall hardness, weight and specific gravity of the core and they are suitably adjusted insofar as the objects of the invention are attainable. Usually, the core has an overall hardness corresponding to a distortion of 2.5 to 4.5 mm, especially 2.8 to 4 mm under a load of 100 kg applied, and a weight of 20 to 40 grams, especially 23 to 37 grams.

In the practice of the invention, no particular limit is imposed on the core-forming composition from which the solid core is formed. The solid core may be formed using a base rubber, a crosslinking agent, a co-crosslinking agent, and an inert filler as used in the formation of conventional solid cores. The base rubber used herein may be natural rubber and/or synthetic rubber conventionally used in solid golf balls although 1,4-cis-polybutadiene having at least 40% of cis-structure is especially preferred in the invention. The polybutadiene may be blended with a suitable amount of natural rubber, polyisoprene rubber, styrenebutadiene rubber or the like if desired. The crosslinking agent includes organic peroxides such as dicumyl peroxide, di-t-butyl peroxide, and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, with a blend of dicumyl peroxide and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane being preferred. In order to form a solid core so as to have the above-defined hardness distribution, it is preferable to use a blend of dicumyl peroxide and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane as the crosslinking agent and the step of vulcanizing at 160° C. for 20 minutes. It is noted that the amount of the crosslinking agent blended is suitably determined although it is usually about 0.5 to 3 parts by weight per 100 parts by weight of the base rubber. The co-crosslinking agent used herein is not critical. Examples include metal salts of unsaturated fatty acids, inter alia, zinc and magnesium salts of unsaturated fatty acids having 3 to 8 carbon atoms (e.g., acrylic acid and methacrylic acid), with zinc acrylate being especially preferred. Examples of the inert filler include zinc oxide, barium sulfate, silica, calcium carbonate, and zinc carbonate, with zinc oxide and barium sulfate being often used. The amount of the filler blended is usually up to 40 parts by weight per 100 parts by weight of the base rubber although the amount largely varies with the specific gravity of the core and cover, the standard weight of the ball, and other factors and is not critical. In the practice of the invention, the overall hardness and weight of the core can be adjusted to optimum values by properly adjusting the amounts of the crosslinking agent and filler (typically zinc oxide and barium sulfate) blended.

The core-forming composition obtained by blending the above-mentioned components is generally milled in a conventional mixer such as a Banbury mixer and roll mill, compression or injection molded in a core mold, and then heat cured under the above-mentioned temperature condition, whereby a solid core having an optimum hardness distribution is obtainable.

The intermediate layer 3 enclosing the core 2 is preferably formed to a JIS-C hardness of 75 to 100 degrees, more preferably 80 to 98 degrees. The intermediate layer is formed to a hardness higher than the core surface hardness by at least 5 degrees, preferably 5 to 20 degrees, more preferably by 7 to 18 degrees. A hardness difference of less than 5 degrees would fail to provide sufficient restitution whereas a hardness difference of more than 20 degrees would result in a dull and rather hard hitting feel. The restitution of the core can be maintained by forming the intermediate layer to a higher hardness than the core surface hardness.

The gage, specific gravity and other parameters of the intermediate layer may be properly adjusted insofar as the objects of the invention are attainable. Preferably the gage is 0.2 to 3 mm, especially 0.7 to 2.3 mm and the specific gravity is 0.9 to less than 1.2, especially 0.94 to 1.15.

Since the intermediate layer 3 serves to compensate for a loss of restitution of the solid core which is formed soft, it is formed of a material having improved restitution insofar as a hardness within the above-defined range is achievable. Use is preferably made of a blend of ionomer resins such as Himilan (manufactured by Mitsui-duPont Polychemical K.K.) and Surlyn (E.I. duPont) as will be described later in Table 2. An intermediate layer-forming composition may be obtained by adding to the ionomer resin, additives, for example, an inorganic filler such as zinc oxide and barium sulfate as a weight adjuster and a coloring agent such as titanium dioxide.

The cover 4 enclosing the intermediate layer 3 must be formed to a lower hardness than the intermediate layer. That is, the cover has a hardness lower than the intermediate layer hardness by at least 5 degrees. Additionally, the cover is preferably formed to a JIS-C hardness of up to 90 degrees, more preferably 70 to 90 degrees, most preferably 75 to 87 degrees when spin properties in an approach range are of much account. A cover hardness in excess of 90 degrees on JIS-C scale would adversely affect the spin properties in an approach range so that professional and skilled amateur players who prefer accurate control reject use in the game. A cover hardness of less than 70 degrees would result in a ball losing restitution.

The gage, specific gravity and other parameters of the cover may be properly adjusted insofar as the objects of the invention are attainable. Preferably the gage is 0.2 to 3 mm, especially 0.7 to 2.3 mm and the specific gravity is 0.9 to less than 1.2, especially 0.93 to 1.15. The gage of the intermediate layer and cover combined is preferably 2 to 4.5 mm, especially 2.2 to 4.2 mm.

The cover composition is not critical and the cover may be formed of any of well-known stock materials having appropriate properties as golf ball cover stocks. For example, ionomer resins, polyester elastomers, and polyamide elastomers may be used alone or in admixture with urethane resins and ethylene-vinyl acetate copolymers. Thermoplastic resin base compositions are especially preferred. UV absorbers, antioxidants and dispersing aids such as metal soaps may be added to the cover composition if necessary. The method of applying the cover is not critical. The cover is generally formed over the core by surrounding the core by a pair of preformed hemispherical cups followed by heat compression molding or by injection molding the cover composition over the core.

Like conventional golf balls, the three-piece solid golf ball of the invention is formed with a multiplicity of dimples in the cover surface. The golf ball of the invention is formed with dimples such that, provided that the golf ball is a sphere defining a phantom spherical surface, the proportion of the surface area of the phantom spherical surface delimited by the edge of respective dimples relative to the overall surface area of the phantom spherical surface, that is the percent occupation of the ball surface by the dimples is at least 62%, preferably 63 to 85%. With a dimple occupation of less than 62%, the above-mentioned flight performance, especially an increased flight distance is not expectable. The total number of dimples is preferably 360 to 450, more preferably 370 to 440. There may be two or more types of dimples which are different in diameter and/or depth. It is preferred that the dimples have a diameter of 2.2 to 4.5 mm and a depth of 0.12 to 0.23 mm. The arrangement of dimples may be selected from regular octahedral, dodecahedral, and icosahedral arrangements as in conventional golf balls while the pattern formed by thus arranged dimples may be any of square, hexagon, pentagon, and triangle patterns.

Moreover, the dimples are preferably formed such that V_0 is 0.39 to 0.6, especially 0.41 to 0.58 wherein V_0 is the volume of the dimple space below a plane circumscribed by the dimple edge divided by the volume of a cylinder whose bottom is the plane and whose height is the maximum depth of the dimple from the bottom.

Now the shape of dimples is described in further detail. In the event that the planar shape of a dimple is circular, as shown in FIG. 2, a phantom sphere 6 having the ball diameter and another phantom sphere 7 having a diameter smaller by 0.16 mm than the ball diameter are drawn in conjunction with a dimple 5. The circumference of the other sphere 7 intersects with the dimple 5 at a point 8. A tangent 9 at intersection 8 intersects with the phantom sphere 6 at a point 10 while a series of intersections 6 define a dimple edge 11. The dimple edge 11 is so defined for the reason that otherwise, the exact position of the dimple edge cannot be determined because the actual edge of the dimple 5 is rounded. The dimple edge 11 circumscribes a plane 12 (having a diameter Dm). Then as shown in FIGS. 3 and 4, the dimple space 13 located below the plane 12 has a volume Vp. A cylinder 14 whose bottom is the plane 12 and whose height is the maximum depth Dp of the dimple from the bottom or circular plane 12 has a volume Vq. The ratio V_0 of the dimple space volume Vp to the cylinder volume Vq is calculated.

$$Vp = \int_0^{\frac{Dm}{2}} 2\pi xy\,dx$$

$$Vq = \frac{\pi Dm^2 Dp}{4}$$

$$V_0 = \frac{Vp}{Vq}$$

In the event that the planar shape of a dimple is not circular, the maximum diameter or length of a dimple is determined, the plane projected shape of the dimple is assumed to be a circle having a diameter equal to this maximum diameter or length, and V_0 is calculated as above based on this assumption.

Furthermore, provided that the number of types of dimples formed in the ball surface is n wherein $n \geqq 2$, preferably n=2 to 6, more preferably n=3 to 5, and the respective types of dimples have a diameter Dmk, a maximum depth Dpk, and a number Nk wherein k=1, 2, 3, . . . , n, the golf ball of the invention prefers that an index Dst of overall dimple surface area given by the following equation (1) is at least 4, more preferably 4 to 8.

$$Dst = \frac{n \sum_{k=1}^{n} [(Dmk^2 + Dpk^2) \times V_0k \times Nk]}{4R^2} \quad (1)$$

Note that R is a ball radius, V_0 is as defined above, and Nk is the number of dimples k. The index Dst of overall dimple surface area is useful in optimizing various dimple parameters so as to allow the golf ball of the invention having the above-mentioned solid core and cover to travel a further distance. When the index Dst of overall dimple surface area is equal to or greater than 4, the aerodynamics (flying distance and flight-in-wind) of the golf ball are further enhanced.

While the three-piece solid golf ball of the invention is constructed as mentioned above, other ball parameters including weight and diameter are properly determined in accordance with the Rules of Golf.

The three-piece solid golf ball of the invention will travel an increased flight distance on full shots with a driver and be easy to control on approach shots with No. 5 iron or sand wedge.

EXAMPLE

Examples of the present invention are given below together with Comparative Examples by way of illustration and not by way of limitation. The amounts of components in the core, intermediate layer, and cover as reported in Tables 1 and 2 are all parts by weight.

Examples 1–5 and Comparative Examples 1–4

Solid cores, Nos. 1 to 6, were prepared by kneading components in the formulation shown in Table 1 to form a rubber composition and molding and vulcanizing it in a mold under conditions as shown in Table 1. The cores were measured for JIS-C hardness and diameter, with the results shown in Tables 3 and 4. The JIS-C hardness of the core was measured by cutting the core into halves, and measuring the hardness at the center (center hardness) and the hardness at core surface or spherical surface (surface hardness). The result is an average of five measurements.

TABLE 1

Core No.	1	2	3	4	5	6
Formulation						
Cis-1,4-poly-butadiene rubber	100	100	100	100	100	100
Zinc acrylate	24	24	25	29	15	34
Zinc oxide	29	26	34	27	33	25
Dicumyl peroxide	1	1	1	1	1	0
*1	0.3	0.3	0.3	0.3	0.3	1
Vulcanizing conditions						
Temperature, °C.	160	160	160	160	160	155
Time, min.	20	20	20	20	20	15
Core hardness*2, mm	3.7	3.7	3.5	3	5.7	2.2

*1 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane (trade name Perhexa 3M-40 manufactured by Nippon Oil and Fats K.K.)
*2 distortion under a load of 100 kg

Next, compositions for the intermediate layer and cover were milled as shown in Table 2 and injection molded over the solid core and the intermediate layer, respectively, obtaining three-piece solid golf balls as shown in Table 4. At the same time as injection molding, two or three types of dimples were indented in the cover surface as shown in Table 3. Whenever the intermediate layer and cover were molded, the intermediate layer and cover were measured for JIS-C hardness, specific gravity and gage. The results are also shown in Table 4.

TABLE 2

Intermediate layer and cover formulations (pbw)					
	A	B	C	D	E
Himilan 1557*3	50	—	50	—	—
Himilan 1601*3	—	—	50	—	—
Himilan 1605*3	50	50	—	—	—
Himilan 1855*3	—	—	—	50	50
Himilan 1856*3	—	—	—	—	50
Himilan 1706*3	—	50	—	—	—
Surlyn 8120*4	—	—	—	50	—

*3 ionomer resin manufactured by Mitsui-duPont Polychemical K.K.
*4 ionomer resin manufactured by E.I. duPont of USA

TABLE 3

Dimple							
Dimple set	Diameter (mm)	Depth (mm)	V_0		Number	Dst	Surface occupation (%)
I	4.000	0.200	0.50		72	4.539	75
	3.850	0.193	0.50		200		
	3.400	0.170	0.50		120		
				total	392		
II	3.800	0.205	0.48		162	4.263	74
	3.600	0.194	0.48		86		
	3.450	0.186	0.48		162		
				total	410		
III	3.400	0.195	0.39		360	2.148	61
	2.450	0.195	0.39		140		
				total	500		

The thus obtained golf balls were evaluated for flight performance, spin, feel, spin control, and durability by the following tests.

Flight performance

Using a hitting machine manufactured by True Temper Co., the ball was actually hit with a driver (#W1) at a head speed of 45 m/s (HS45) and 35 m/sec. (HS35) to measure a spin, carry, and total distance.

Feel

Five golfers with a head speed of 45 m/sec. (HS45) and five golfers with a head speed of 35 m/sec. (HS35) actually hit the balls. The ball was rated according to the following criterion.

O:soft

Δ:ordinary

X:hard

Spin control

Three professional golfers actually hit the ball with No. 5 iron (#I5) to examine intentional hook and slice and stoppage on the green and also with a sand wedge (#SW) to examine spin on 30 and 80 yard shots (that is, stoppage on the green and ease of capture of the ball upon impact). An overall rating of the ball was derived from these spin control factors. The ball was rated "O" for easy control, "Δ" for ordinary, and "X" for difficult control.

Durability

Durability against continuous strikes and durability against cutting were evaluated in combination. The ball was rated according to the following criterion.

O:excellent

Δ:ordinary

X:inferior

TABLE 4

	Examples					Comparative Examples			
	1	2	3	4	5	1	2	3	4
Core									
Type	1	2	3	4	1	1	5	6	4
Center hardness A (JIS-C)	64	64	65	68	64	64	52	80	68
Surface hardness B (JIS-C)	75	75	77	82	75	75	62	90	82
B − A	11	11	12	14	11	11	10	10	14
Diameter (mm)	36.5	37.9	35.1	37.9	36.5	36.5	36.5	36.5	37.9
Intermediate layer									
Type	A	A	B	B	C	A	D	B	A
Hardness C (JIS-C)	86	86	93	93	83	86	75	93	86
C − B	11	11	16	11	8	11	13	3	4
Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Gage (mm)	1.6	1.2	1.8	1.2	1.6	1.6	1.6	1.6	1.8
Cover									
Type	E	E	C	F	D	E	B	A	B
Hardness D (JIS-C)	80	80	83	80	75	81	93	86	93
D − C	−6	−6	−10	−13	−8	−5	18	−7	7
Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Gage (mm)	1.5	1.5	2.0	1.5	1.5	1.5	1.5	3.5	2.0
Intermediate layer/cover combined gage (mm)	3.1	2.7	3.8	2.7	3.1	3.1	3.1	5.1	3.8
Dimple set	I	I	II	II	II	III	I	I	I
Ball outer diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
#W1/HS45									
Spin (rpm)	2800	2750	2900	2700	2950	2800	2650	2700	2680
Carry (m)	209.0	210.0	210.0	209.5	210.5	207.0	209.0	207.5	208.5
Total (m)	223.0	224.5	223.5	222.0	224.0	218.0	221.0	217.0	218.0
Feel	O	O	O	O	O	O	Δ	X	X
#W1/HS35									
Spin (rpm)	4600	4400	4650	4700	4750	4600	4600	4680	4630
Carry (m)	142.0	144.0	142.5	144.0	143.0	138.0	142.5	139.0	140.0
Total (m)	150.0	153.0	150.0	152.5	152.0	145.0	149.5	145.5	148.0
Feel	O	O	O	O	Δ	O	Δ	X	X
Spin control	O	O	O	O	O	O	X	Δ	X
Durability	O	O	O	O	O	O	X	Δ	Δ

Note:
A hardness difference is represented by (B − A), (C − B), and (D − C). (B − A) is equal to the core surface hardness minus the core center hardness; (C − B) is equal to the intermediate layer hardness minus the core surface hardness; and (D − C) is equal to the cover hardness minus the intermediate layer hardness.

As is evident from Table 4, the ball of Comparative Example 1 which is identical with the ball of Example 1 except for the dimple set is unsatisfactory in flight distance because the dimple surface occupation is as low as 61%. The ball of Comparative Example 2 is inferior in hitting feel, spin control, and durability since the cover is harder than the intermediate layer. The ball of Comparative Example 3 is unsatisfactory in flight distance and hitting feel because the core surface hardness and core center hardness are too high and the hardness difference between the intermediate layer and the core surface is too small. The ball of Comparative Example 4 is inferior in flight distance, hitting feel, and spin control since the cover is harder than the intermediate layer and the intermediate layer is insufficiently harder than the core.

In contrast, the golf balls of Examples 1 to 5 within the scope of the invention receive an appropriate spin rate upon full shots with a driver to travel a longer flight distance, are easy to spin control upon approach shots, and are excellent in both hitting feel and durability.

Japanese Patent Application No. 82121/1996 is incorporated herein by reference.

Although some preferred embodiments have been described, many modifications and variations may be made thereto in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

We claim:

1. A three-piece solid golf ball of the three-layer structure comprising a solid core, an intermediate layer, and a cover, having a plurality of dimples in the ball surface wherein

the solid core, intermediate layer, and cover each have a hardness as measured by a JIS-C scale hardness meter wherein the core center hardness is up to 75 degrees, the core surface hardness is up to 85 degrees, the core surface hardness is higher than the core center hardness by 8 to 20 degrees, the intermediate layer hardness is higher than the core surface hardness by at least 5 degrees, and the cover hardness is lower than the intermediate layer hardness by at least 5 degrees, and

the dimples occupy at least 62% of the ball surface.

2. The three-piece solid golf ball of claim 1 wherein said intermediate layer has a gage of 0.2 to 3 mm and a specific gravity of 0.9 to less than 1.2.

3. The three-piece solid golf ball of claim 1 wherein said cover is based on a thermoplastic resin and has a hardness of up to 90 degrees as measured by the JIS-C scale hardness meter.

4. The three-piece solid golf ball of claim 1 wherein said cover has a gage of 0.2 to 3 mm and a specific gravity of 0.9 to less than 1.2.

5. The three-piece solid golf ball of claim 1 wherein said solid core is formed of a cis-1,4-polybutadiene base elastomer and has a diameter of 34 to 41 mm.

6. The three-piece solid golf ball of claim 1 wherein the dimples in the ball surface total in number to 360 to 450 and include at least two types of dimples having different

diameters, and an index (Dst) of overall dimple surface area given by the following expression is at least 4,

$$Dst = \frac{n \sum_{k-1}^{n} [(Dmk^2 + Dpk^2) x V_0 k x Nk]}{4R^2}$$

wherein R is a ball radius, n is the number of dimple types (n≧2), Dmk is a diameter of dimples k, Dpk is a depth of dimples k, Nk is the number of dimples k wherein k=1, 2, 3, . . . n, and V_0, is the volume of the dimple space below a plane circumscribed by the dimple edge divided by the volume of a cylinder whose bottom is the plane and whose height is the maximum depth of the dimple from the bottom.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,782,707
DATED : July 21, 1998
INVENTOR(S) : Hisashi Yamagishi et al.

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Please add claims 7-17 as follows:

7. The three-piece solid golf ball of claim 6 wherein Dmk is in the range of 2.2 to 4.5 and Dpk is in the range of 0.12 to 0.23 mm.

8. The three-piece solid golf ball of claim 6 wherein V_0 is in the range of 0.39 to 0.6.

9. The three-piece solid golf ball of claim 1 wherein said core center hardness is in the range of 60 to 73 as measured on JIS-C.

10. The three-piece solid golf ball of claim 1 wherein said core has a surface hardness in the range of 70 to 83 degrees on JIS-C.

11. The three-piece solid golf ball of claim 1 wherein said core surface hardness is higher than the center hardness by 10 to 18 degrees.

12. The three-piece solid golf ball of claim 1 wherein said solid core has a distortion in the range of 2.5 to 4.5 mm under an applied load of 100 kg.

13. The three-piece solid golf ball of claim 1 wherein said intermediate layer has a hardness in the range of 75 to 100 degrees measured on JIS-C.

14 The three-piece solid golf ball of claim 1 wherein said intermediate layer has a hardness higher than the core surface hardness by t to 20 degrees.

15. The three-piece solid golf ball of claim 1 wherein said cover has a hardness in the range of 70 to 90 degrees measured on JIS-C.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,782,707
DATED : July 21, 1998
INVENTOR(S) : Hisashi Yamagishi et al.

Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

16. The three-piece solid golf ball of claim 1 wherein the gage of the intermediate layer and the cover combined is in the range of 2 to 4.5 mm.

17. The three-piece solid golf ball of claim 1 wherein said dimples occupy 63 to 85% of the ball surface

Signed and Sealed this

Sixth Day of November, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer

Acting Director of the United States Patent and Trademark Office

EXHIBIT 14

US005743817A

United States Patent [19]

Yamagishi et al.

[11] Patent Number: 5,743,817

[45] Date of Patent: Apr. 28, 1998

[54] GOLF BALL

[75] Inventors: Hisashi Yamagishi; Yoshinori Egashira; Hideo Watanabe, all of Chichibu, Japan

[73] Assignee: Bridgestone Sports Co., Ltd., Tokyo, Japan

[21] Appl. No.: 536,049

[22] Filed: Sep. 29, 1995

[30] Foreign Application Priority Data

Oct. 14, 1994 [JP] Japan 6-276109
Dec. 14, 1994 [JP] Japan 6-333024

[51] Int. Cl.[6] A63B 37/06; A63B 37/12

[52] U.S. Cl. 473/377; 473/351; 473/385

[58] Field of Search .... 473/372, 373, 473/351, 377, 385, 370, 374, DIG. 22

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Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas, PLLC

[57] ABSTRACT

A solid golf ball comprising a core and a cover is provided. The core has a core hardness expressed by a distortion of 2.2–4.0 mm under a load of 100 kg. The core hardness divided by the ball hardness ranges from 1.0 to 1.3. The cover has a thickness of 1.3–1.8 mm. The ball is improved in feel and spin while maintaining the flying distance inherent to solid golf balls.

2 Claims, 1 Drawing Sheet

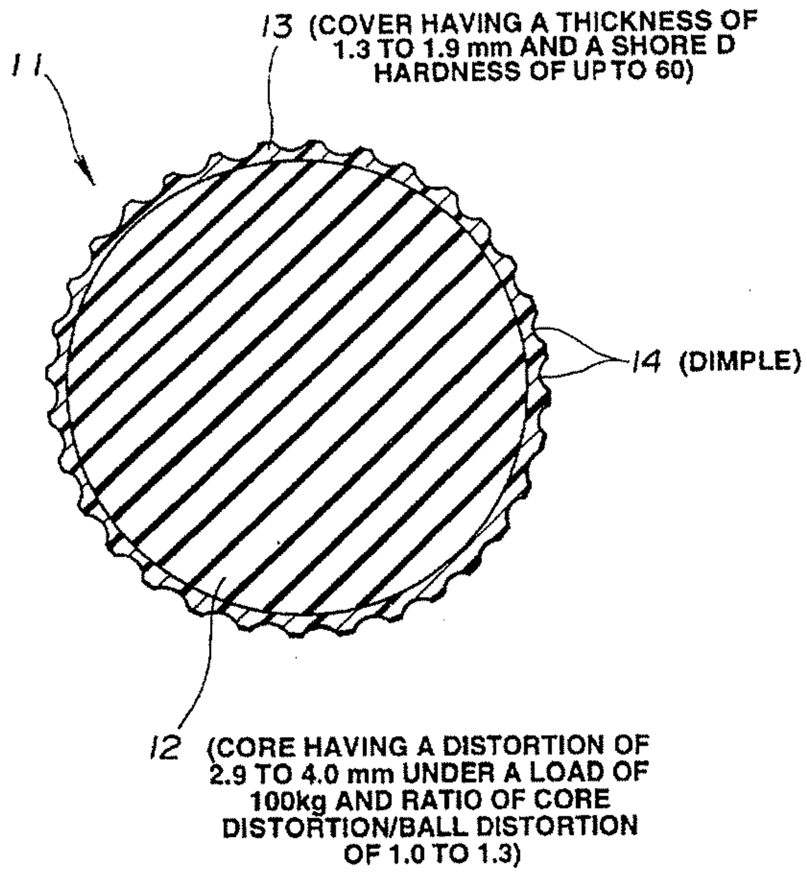
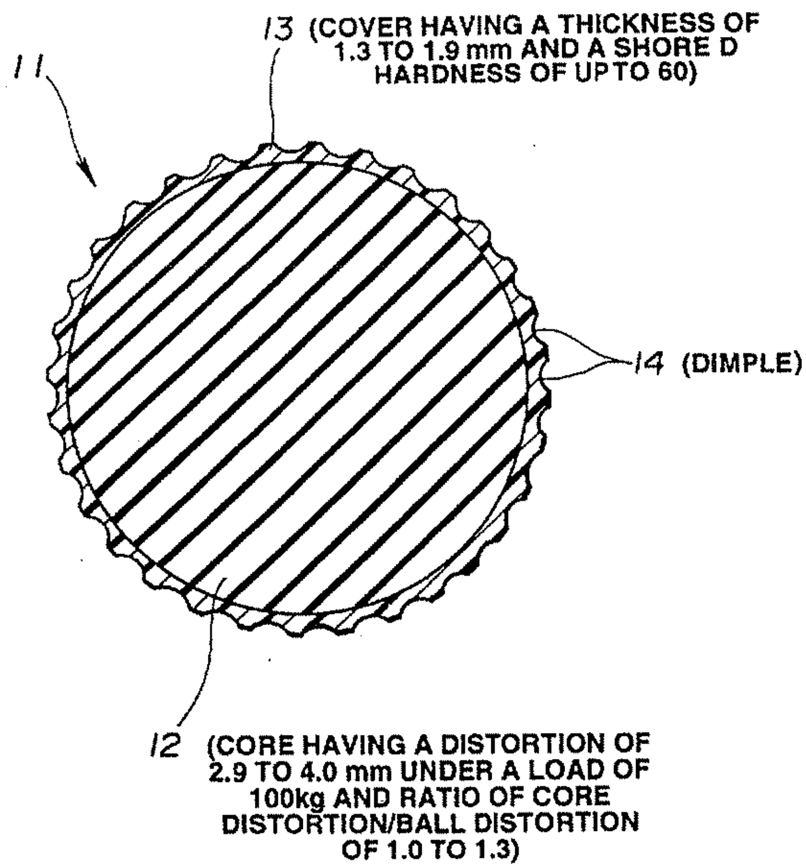


FIG.1


13 (COVER HAVING A THICKNESS OF 1.3 TO 1.9 mm AND A SHORE D HARDNESS OF UP TO 60)
11
14 (DIMPLE)
12 (CORE HAVING A DISTORTION OF 2.9 TO 4.0 mm UNDER A LOAD OF 100kg AND RATIO OF CORE DISTORTION/BALL DISTORTION OF 1.0 TO 1.3)

GOLF BALL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a solid golf ball having improved feel and spin performance.

2. Prior Art

As compared with wound golf balls, two-piece golf balls and other solid golf balls are advantageous in gaining a flying distance since they fly along the trajectory of a straight ball when hit by both drivers and irons. This advantage is mainly attributable to their structure. Because of their configuration less receptive to spin, the solid golf balls are given a straight ball trajectory and yield a more run, resulting in an increased total flying distance.

In turn, the solid golf ball tends to draw a "flier" path on an iron shot since it is less receptive to spin and does not readily stop on the green. Because of such characteristics, the two-piece balls are not preferred by experienced players.

Therefore, there is a need for a solid golf ball having improved spin properties and allowing the player to aim the pin dead with an iron. The increased flying distance inherent to the solid golf ball should be maintained and of course, the ball should have a pleasant feel.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a solid golf ball such as a two-piece golf ball which is improved in feel, spin properties and iron control without detracting from the trajectory and flying distance inherent to the solid golf ball. The term iron control is the controllability of a ball on an iron shot, more specifically stop on the green.

Briefly stated, the present invention pertains to a solid, typically two-piece, golf ball comprising a core and a cover enclosing the core. The hardness of the core, cover and ball are referred to as core hardness, cover hardness, and ball hardness, respectively. According to the invention, the core hardness is such that the core undergoes a distortion of at least 2.2 mm under a load of 100 kg. The core hardness divided by the ball hardness is in the range of 1.0 to 1.3. The cover has a radial thickness of 1.3 to 1.8 mm. This parameter control leads to a golf ball satisfying the requirements of flying distance, feel and spin.

Consider the spin mechanism of golf balls made of the same materials, but changed in hardness. Provided that the club head speed and the cover material are identical, the coefficient of friction between the ball and the club face is identical and hence, an identical frictional force is exerted therebetween. Only distortion is different due to differential hardness. Then the distance between the center of gravity and the ball-club contact point is different. The harder the ball, the longer is the contact point distance. The softer the ball, the shorter is the contact point distance. Then harder balls are more receptive to spin.

The spinning mechanism associated with an iron suggests that the spin quantity can be increased by increasing the ball hardness. Increasing the ball hardness, however, gives a harder feel, exacerbating the hitting feel. The spin quantity can also be increased by making the cover softer. A softer cover, however, deprives the ball of repulsion, resulting in a loss of initial speed and flying distance.

Attempting to increase the spin quantity for improving spin properties by using a soft material, typically a material having a Shore D hardness of 60 or lower as the cover, we found that a low hardness cover lowers repulsion, resulting

in a loss of flying distance on hitting. Quite unexpectedly, we have found that by adjusting the core hardness to a distortion of at least 2.2 mm under a load of 100 kg, the ratio of core hardness to ball hardness to range from 1.0 to 1.3 and the cover thickness to range from 1.3 mm to 1.8 mm, the golf ball, whose cover is made of a softer material, is improved in iron control (that is, stop on the green) without deterring the feel and flying distance and without losing the trajectory and flying distance on a driver shot inherent to solid golf balls.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic cross section illustrating one embodiment of the golf ball of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the golf ball comprising a spherical solid core enclosed in a cover according to the present invention, the core hardness is at least 2.2 mm as expressed by a distortion under a load of 100 kg, the core hardness divided by the ball hardness is in the range of 1.0 to 1.3 and the cover has a thickness of 1.3 to 1.8 mm.

The core hardness and ball hardness are defined by distortions (in mm) of the core and ball under a load of 100 kg, respectively. The core hardness corresponds to such a distortion of at least 2.2 mm, preferably at least 2.5 mm, more preferably 2.5 to 4.0 mm, most preferably 3.0 to 4.0 mm. With a core distortion of less than 2.2 mm, the feel becomes unpleasant. Too much core distortions would result in balls having poor restitution, low flying performance and a too soft feel. By controlling the core hardness/ball hardness so as to fall in the range between 1.0 and 1.3, especially between 1.0 and 1.25, the solid golf ball, typically two-piece golf ball is improved in feel, flying distance and spin characteristics. If the core hardness/ball hardness is less than 1.0, the feel becomes unpleasant. If the core hardness/ball hardness exceeds 1.3, the ball loses a quick stop on the green.

It is understood that the golf ball of the invention is advantageously applied to two-piece golf balls having a single core. It is also applicable to multi-core golf balls having a core consisting of two or more layers, such as three-piece golf balls. In an example where the core consists of two inner and outer layers, the core hardness refers to the hardness of the spherical two-layer core as a whole. Differently stated, the core hardness refers to the hardness of an entire spherical core left after removing the cover from the ball.

The cover has a Shore D hardness of up to 60, especially 55 to 60. A cover hardness of more than 60 would adversely affect spin characteristics and stop on the green. Since a cover with too low hardness would result in poor repulsion and a loss of flying distance, the lower limit of 55 is recommended for the cover hardness.

According to the invention, the cover has a radial thickness of 1.3 to 1.8 mm, especially 1.4 to 1.8 mm. Outside the range, the objects of the invention cannot be achieved. A cover of thinner than 1.3 mm is less resistant against top damage and liable to be broken. A cover of thicker than 1.8 mm leads to losses of repulsion and flying performance and gives a dull feel.

In general, the flying distance the ball covers depends on the head speed. The flying distance is reduced by a change from a higher head speed to a lower head speed. The degree

of reduction of the flying distance by a change from a higher head speed to a lower head speed can be suppressed by limiting the cover thickness to the above-defined range. Differently stated, the dependency of flying distance on head speed is alleviated. Therefore, the ball of the invention is suitable for senior and female players who swing at a relatively low head speed.

In one preferred embodiment of the invention, the golf ball has a spin factor of 1.0 to 1.5. The spin factor is defined as follows. The golf ball has a spin quantity when hit by a pitching wedge (referred to as wedge spin quantity) and a spin quantity when hit by a driver (referred to as driver spin quantity). The spin factor is obtained by dividing the ratio of the wedge spin quantity to the driver spin quantity by the ball hardness. Then a spin factor smaller than unity means that the ball has greater spin with the driver and less spin with the pitching wedge. The former indicates that the trajectory is lofted and the flying distance is reduced. The latter indicates that when hit with an iron, the ball draws a flier-like trajectory and flies too much. A greater spin factor is then desirable. Then the object of the invention to render the ball receptive to less spin with a driver and more spin with an iron is effectively accomplished. However, a too greater spin factor would exacerbate ball control on an iron shot because the ball can be moved back too much due to back spin. For this reason, the spin factor is preferably in the range between 1.0 and 1.5.

The golf ball of the invention is advantageously applied to two-piece golf balls while it is also applicable to multi-core golf balls such as three-piece golf balls. The material and preparation of the core and cover are not critical. The components may be made of any of well-known materials insofar as the requirements of the invention are met. Of course, the golf ball of the invention has a standard size and weight.

More particularly, the core of the present solid golf ball is formed from a rubber composition by a conventional method while properly adjusting the component proportion and vulcanizing conditions. The core composition generally includes a base rubber, a crosslinking agent, a co-crosslinking agent, an inert filler, and other components. The base rubber may be selected from natural and synthetic rubbers conventionally used in the manufacture of solid golf balls. Preferably the base rubber is 1,4-polybutadiene rubber containing at least 40% of cis-configuration, optionally in admixture with natural rubber, polyisoprene rubber or styrene-butadiene rubber. The crosslinking agent is preferably selected from organic peroxides such as dicumyl peroxide and di-t-butyl peroxide, with the dicumyl peroxide being more preferred. Preferably the crosslinking agent is blended in an amount of about 0.5 to 3 parts, more preferably about 0.8 to 1.5 parts by weight per 100 parts by weight of the base rubber. Non-limiting examples of the co-crosslinking agent include metal salts of unsaturated fatty acids, especially zinc and magnesium salts of unsaturated fatty acids having 3 to 8 carbon atoms, such as acrylic acid and methacrylic acid. Zinc acrylate is the most preferred salt. The co-crosslinking agent is preferably blended in an amount of about 24 to 38 parts, more preferably about 28 to 34 parts by weight per 100 parts by weight of the base rubber. Examples of the inert filler include zinc oxide, barium sulfate, silica, calcium carbonate, and zinc carbonate, with the zinc oxide being most often used. The amount of the filler blended depends on the desired specific gravity of the core and cover, ball weight, and other factors although it generally ranges from about 10 to about 60 parts by weight per 100 parts by weight of the base rubber.

These components are blended to form a core-forming rubber composition which is kneaded by means of a conventional kneading machine such as a Banbury mixer and

roll mill and then compression or injection molded in a spherical mold cavity. The molded composition is cured by heating it at a sufficient temperature for the crosslinking and co-crosslinking agents to exert their function (for example, about 130° to 170° C. when the crosslinking agent is dicumyl peroxide and the co-crosslinking agent is zinc acrylate). In this way, a solid spherical core having a diameter of 37 to 40 mm is prepared.

In the case of a two layer core, the inner core may be made of the same composition as above and the outer core may be made of a similar rubber composition or a resin composition based on an ionomer resin or the like. The outer core may be formed by compression molding or injection molding it around the inner core. Typically the inner core has a diameter of 27.0 to 38.0 mm, preferably 28.0 to 36.0 mm and the outer core has a diameter of 0.5 to 6.5 mm, preferably 1.5 to 5.5 mm, and the total diameter ranges from 37 to 40 mm.

The solid core is enclosed with the cover by any desired technique, for example, by enclosing the core in a pair of semi-spherical shell halves followed by heat compression molding. Alternatively the core is directly covered with a cover material by injection molding. By properly selecting the material and amount of the core and cover and preparation conditions such as vulcanizing conditions, a golf ball satisfying the requirements of the invention can be prepared.

There has been described a golf ball which is improved in feel and spin characteristics while maintaining the flying distance inherent to solid golf balls and which undergoes a lower degree of reduction of its flying distance upon hitting at a lower head speed.

EXAMPLE

Examples of the present invention are given below by way of illustration and not by way of limitation.

Examples 1–6 and Comparative Examples 1–2

Cores having a hardness as shown in Table 1 were molded by vulcanizing in a mold rubber compositions comprising cis-1,4-polybutadiene rubber, zinc acrylate, zinc oxide, and dicumyl peroxide. The core hardness reported is a distortion in millimeter under a load of 100 kilograms.

The cores were enclosed with covers which were formed from mixtures of ionomer resins. The blending proportion of ionomer resins was changed to form covers having varying hardness (Shore D scale) as shown in Table 2. In this way, there were obtained large-size two-piece golf balls having a hardness as shown in Table 3. The ball hardness reported is again a distortion in millimeter under a load of 100 kilograms.

The base composition for the core consisted of the following components.

	Parts by weight
cis-1,4-polybutadiene rubber (BR01)	100
zinc acrylate	33.2
zinc oxide	10
barium sulfate	9.7
anti-oxidant	0.2
dicumyl peroxide	0.9

Cores having varying hardness and specific gravity were obtained by varying the amounts of zinc acrylate and barium sulfate as shown in Table 1.

TABLE 1

Core hardness	Cover gage 1.4 mm	1.6 mm	1.8 mm	2.0 mm	2.4 mm
2.48–2.50 mm	33.0	33.0	33.0	33.0	
	6.4	7.5	8.6	9.7	
2.88–2.91 mm	31.0	31.0	31.0	31.0	31.0
	7.8	8.8	9.9	11.0	13.9
3.25–3.30 mm	28.0	28.0	28.0	28.0	
	9.1	10.2	11.2	12.3	

At the upper and lower stages for each core hardness and cover gage combination, the amounts of zinc acrylate and barium sulfate are reported in parts by weight, respectively.

The base composition for the cover was a 50/50 (by weight) mixture of ionomer resins, Himilan 1650 and Surlyn 8120. Covers having varying hardness were obtained while blending Himilan 1650 and Surlyn 8120 in a ratio as shown in Table 2.

TABLE 2

Cover hardness (Shore D)	Resin mix	Weight ratio
56	H1650/S8120	40/60
57	H1650/S8120	50/50
65	H1605/H1706	50/50

* H: Himilan commercially available from du Pont-Mitsui Polychemical Co., Ltd.
S: Surlyn commercially available from E. I. duPont

The golf balls were examined for fly, stop on the green, and feel by the following procedures.

Fly Test

Using a swing robot manufactured by True Temper Co., the ball was hit by a driver at a head speed (HS) of 45 m/s and by an iron at a head speed of 35 m/s to measure the flying distance.

Stop on the Green Test

Using a swing robot manufactured by True Temper Co., the ball was hit by a pitching wedge at a head speed of 35 m/s so as to fly directly on the green. The distance between the landing and stop positions was measured. A negative value is the distance the ball covers due to back spin. A positive value is a run in a flying direction. The stop on the green was rated "O" for quick stop and "X" for non-stopping.

Feel Test

In a sensory test, a player hit the ball at a head speed (HS) of 35 m/s. The ball feel was rated "very soft", "soft" or "hard".

Note that the dependency of flying distance on head speed is expressed by the flying distance at a head speed of 35 m/s divided by the flying distance at a head speed of 45 m/s and simply reported under the heading "HS35/HS45" in Table 3.

TABLE 3

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Comparative Example 1	Comparative Example 2
Core hardness (mm)	2.48	3.30	2.50	2.90	2.91	3.25	2.10	2.85
Ball hardness (mm)	2.36	3.10	2.30	2.71	2.65	2.90	1.90	2.10
Core/ball hardness ratio	1.05	1.06	1.09	1.07	1.10	1.12	1.11	1.36
Cover thickness (mm)	1.4	1.4	1.6	1.6	1.8	1.8	1.8	2.4
Cover hardness (Shore D)	56	57	56	56	56	57	57	65
Feel @ HS35	soft	very soft	soft	very soft	soft	very soft	hard	soft
Flying distance (m)								
@ HS 35	154	160	154	158	157	159	147	148
@ HS 45	234	237	232	233	233	236	228	235
Stop on the green								
Landing-to-stop distance (m)	−0.5	0.5	0.0	0.0	0.0	0.5	0.0	2.5
Rating	o	o	o	o	o	o	o	x
HS35/HS45	0.658	0.675	0.664	0.678	0.674	0.673	0.645	0.630

Although some preferred embodiments have been described, many modifications and variations may be made thereto in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

We claim:

1. A golf ball comprising a core and a cover wherein said core and said ball has a core hardness and a ball hardness respectively, wherein said core has a distortion of 2.9 to 4.0 mm under a load of 100 kg, the ratio of a core distortion under a load of 100 kg divided by a ball distortion under a load of 100 kg ranges from 1.0 to 1.3, and said cover consists of an ionomer resin as a resin component and has a thickness of 1.3 to 1.8 mm and a Shore D hardness of up to 60.

2. The golf ball of claim 1 wherein said cover has a thickness of 1.6 to 1.8 mm.

* * * * *

EXHIBIT 15

US005553852A

United States Patent [19]

Higuchi et al.

[11] **Patent Number: 5,553,852**

[45] **Date of Patent: Sep. 10, 1996**

[54] **THREE-PIECE SOLID GOLF BALL**

[75] Inventors: **Hiroshi Higuchi; Hisashi Yamagishi**, both of Yokohama; **Yoshinori Egashira**, Hidaka; **Tadatoshi Yamada**, Mitaka, all of Japan

[73] Assignee: **Bridgestone Sports Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **271,953**

[22] Filed: **Jul. 8, 1994**

[30] **Foreign Application Priority Data**

Jul. 8, 1993 [JP] Japan 5-193065

[51] **Int. Cl.^{6}** **A63B 37/06**

[52] **U.S. Cl.** **473/373**; 473/378

[58] **Field of Search** 273/228, 230, 273/218, 220, 219, 225, 229, 214, 217

[56] **References Cited**

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[57] **ABSTRACT**

A three-piece solid golf ball comprising a center core, an intermediate layer, and a cover. The center core (1) has a diameter of at least 29 mm, a hardness in the range of 45–80 JIS C and a specific gravity of less than 1.4. The intermediate layer (2) has a thickness of at least 1 mm, a specific gravity of less than 1.2, and a hardness of at least 85 on JIS C scale. The cover (3) has a thickness of 1–3 mm and a hardness of 50–85 JIS C. The ball has a good total balance of properties in that feeling and controllability are improved at no sacrifice of flying performance and durability.

8 Claims, 1 Drawing Sheet

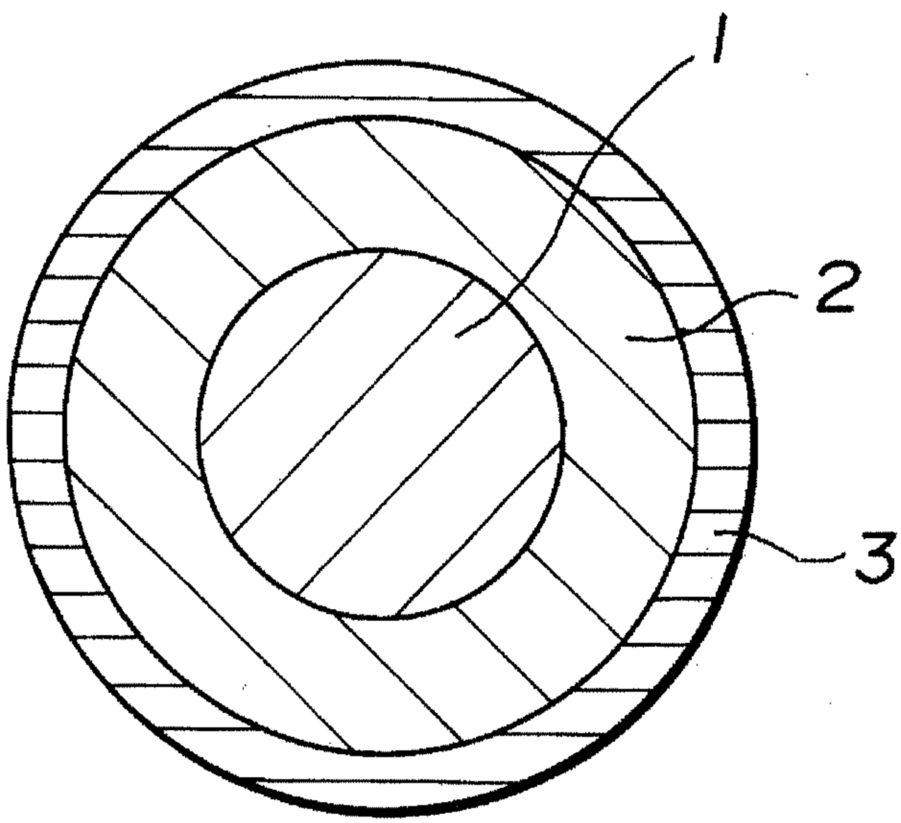
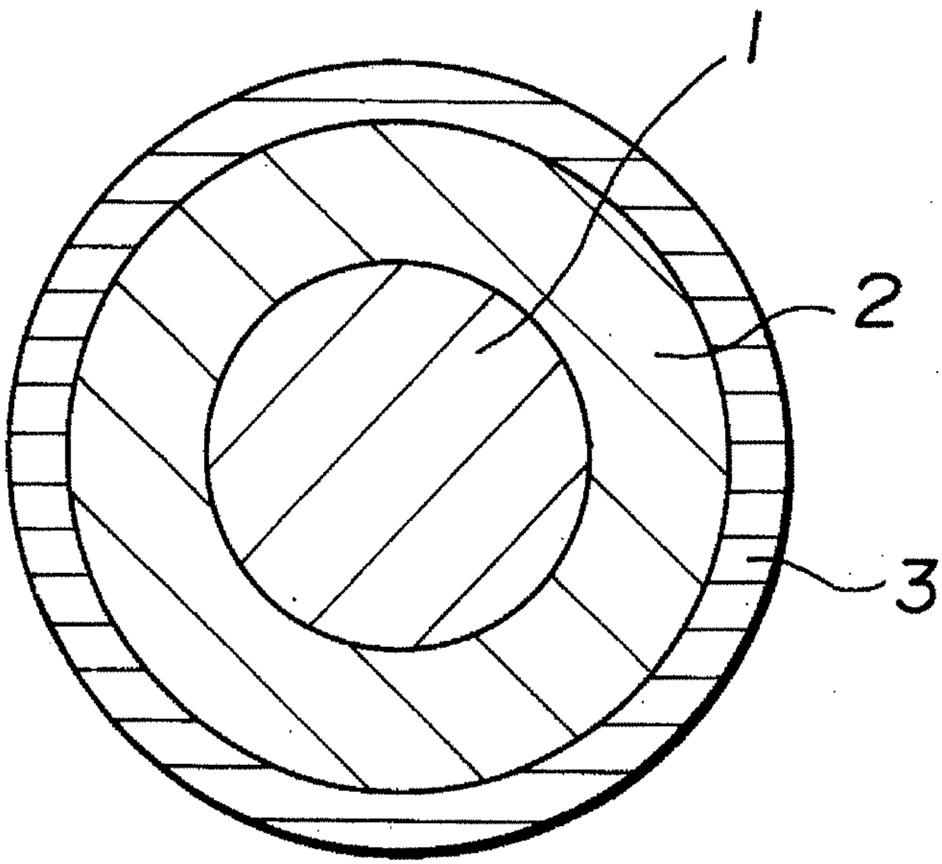


FIG.1



THREE-PIECE SOLID GOLF BALL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to three-piece solid golf balls comprising a center core, an intermediate layer, and a cover and more particularly, to three-piece solid golf balls which are improved in feeling on impact, controllability, and durability.

2. Prior Art

Among a variety of golf balls, thread-wound golf balls and solid golf balls are now popular. The solid golf balls are currently increasing to be a mainstream product. Among them, two-piece solid golf balls consisting of a core and a cover are most widespread.

Most amateur golfers are fond of two-piece solid golf balls which have excellent flying performance and durability although these balls have the disadvantages of a very hard feel on hitting and low control due to rapid ball separation on hitting. For this reason, many of professional golfers and skilled amateur golfers who impose weight on feeling and control prefer wound golf balls, especially wound golf balls using a soft balata cover, to two-piece solid golf balls. The wound golf balls are superior in feeling and control, but inferior in flying distance and durability to the two-piece solid golf balls.

Under the present situation that two-piece solid golf balls and wound golf balls have contradictory characteristics as mentioned above, players make a choice of golf balls depending on their own skill and taste.

In order to develop solid golf balls having a hitting feel approximate to the wound golf balls, two-piece solid golf balls of the soft type have been considered. For such two-piece solid golf balls of the soft type, soft cores must be used. If the cores are soft, however, repulsion becomes low with a concomitant loss of flying performance and durability is considerably deteriorated. That is, the superior flying performance and durability which are a characteristic of two-piece solid golf balls are lost, and in an extreme case, the balls become unacceptable for practical use.

Controllability, which is required even on full shots with drivers, is most important on control shots like approach shots. In an exemplary situation that the next shot should fly beyond the bunker and a short distance from the green edge to the cup, the player who is either professional or amateur will naturally wish to hit a ball with a minimal run. Such controllability of a golf ball largely depends on spin properties.

On a full shot with a club having a relatively large loft, the club loft is dominant to that the ball itself so that almost all balls are given an appropriate amount of spin and few balls overrun. However, on a approach shot over a short distance of 30 or 50 yards, balls will significantly vary in run or controllability. The major factor causing such a difference is not a basic structure, but the identity of cover material. In two-piece solid golf balls, however, covers made of soft material are effective for improving controllability, but detrimental for gaining flying distance.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a solid golf ball which is improved in feeling and controllability while maintaining the superior flying performance and durability which are characteristic of solid golf balls, that is, improved in total balance.

In connection with a solid golf ball having a core forming the center and a cover forming the outermost layer, the inventors have found that by providing a relatively hard intermediate layer between the center core and the cover, and controlling the size and specific gravity of the core, intermediate layer and cover, the center core and core can be made relatively soft to improve feeling and controllability without deteriorating flying performance and durability. The feeling and controllability can be improved in a favorable way.

Briefly stated, an intermediate layer having a thickness of at least 1 mm, a specific gravity of less than 1.2, and a hardness of at least 85 on JIS C scale is formed around a center core having a diameter of at least 29 mm and a specific gravity of less than 1.4 and greater than the intermediate layer specific gravity. A cover having a thickness of 1 to 3 mm is formed on the outer surface of the intermediate layer to complete a solid golf ball. Then even when the center core is softened to a JIS C scale hardness of 45 to 80 and the cover softened to a JIS C scale hardness of 50 to 85, the feeling and controllability can be improved at no sacrifice of flying distance and durability. Further when the intermediate layer is formed of a resin composition based on a high repulsion ionomer resin, the hitting feel and controllability can be further improved with no sacrifice of flying distance and durability.

The present invention provides a three-piece solid golf ball comprising a center core, an intermediate layer, and a cover wherein the center core has a diameter of at least 29 mm and a specific gravity of less than 1.4, the intermediate layer has a thickness of at least 1 mm, a specific gravity of less than 1.2, and a hardness of at least 85 on JIS C scale. The cover has a thickness of 1 to 3 mm. The specific gravity of the intermediate layer is lower than the specific gravity of the center core. In one preferred embodiment, the intermediate layer is formed of a composition based on a high repulsion ionomer resin.

BRIEF DESCRIPTION OF THE DRAWING

The sole figure, FIG. 1 is a schematic cross section of a three-piece solid golf ball according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is schematically illustrated a typical three-piece solid golf ball according to the invention. The ball includes a spherical center core 1 forming the center of the ball and a cover 3 forming the outermost layer of the ball. A relatively hard intermediate layer 2 is disposed between the core 1 and the cover 3. The size and specific gravity of the core 1, intermediate layer 2, and cover 3 are set in specific ranges.

The center core has a diameter of at least 29 mm, preferably 29 to 37 mm and a specific gravity of less than 1.4, preferably 1.05 to 1.38. With a diameter of less than 29 mm, the intermediate layer must be relatively thick with losses of repulsion and feeling. With a specific gravity of 1.4 or more, the ball has a heavier weight which exceeds the weight requirement of golf balls.

On an impact entailing substantial deformation as found on driver shots, the player gets a feeling which largely depend on the hardness of the center core 1 and varies with the club head speed given by the player. Therefore, the

hardness of the center core 1 should be set in accordance with the head speed of the target players. In this sense, the center core hardness is not particularly limited although it preferably ranges from 45 to 80, more preferably from 60 to 80 on JIS C scale (at the center core surface).

The center core 1 is generally formed from a well-known rubber composition comprising a base rubber, co-crosslinking agent and peroxide through heating, pressing and molding steps. The base rubber may be one conventionally used in solid golf balls and preferably be selected from polybutadiene rubber and mixtures of polybutadiene rubber and polyisoprene rubber. Use of 1,4-polybutadiene rubber containing more than 90% of cis structure is preferred for high repulsion. The co-crosslinking agents used in conventional solid golf balls include zinc and magnesium salts of unsaturated fatty acids such as methacrylic acid and acrylic acid and esters of unsaturated fatty acids such as trimethylpropane trimethacrylate and they may be used in the present invention. Zinc acrylate is preferred for high repulsion. The co-crosslinking agent is blended in amounts of about 15 to 30 parts by weight per 100 parts by weight of the base rubber. The peroxide may be selected from a variety of peroxides, preferably dicumyl peroxide and mixtures of dicumyl peroxide and 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane. The peroxide is blended in amounts of about 0.5 to 1 part by weight per 100 parts by weight of the base rubber. If desired, zinc oxide and barium sulfate may be blended in the rubber composition for specific gravity adjustment while antioxidants may also be blended.

The intermediate layer 2 has a radial thickness of at least 1 mm, preferably 1.5 to 3.5 mm, a specific gravity of less than 1.2, preferably 0.9 to 1 and lower than the center core specific gravity, and a hardness of at least 85, preferably 85 to 100 on JIS C scale. With a thickness of less than 1 mm, repulsion is lowered to reduce flying distance. With a specific gravity of 1.2 or more, the center core must have a relatively low specific gravity so that the golf ball may be increased in inertia moment and reduced in spin property and thus lose some controllability. A similar detrimental effect is observed when the intermediate layer specific gravity is greater than the center core specific gravity. A layer with a JIS C scale hardness of less than 85 detracts from flying performance. The intermediate layer preferably has an outer diameter of 38 to 41 mm though not limited thereto. Also preferably the difference in specific gravity between the center core and the intermediate layer is 0.1 or more, especially 0.1 to 0.5 though not limited thereto.

The intermediate layer 2 is effective in compensating for lowering repulsion of the center core 1 which is made soft. It is then formed of a relatively hard (JIS C scale hardness≧85), repulsive material. Although the material is not critical, preferred materials are ionomer resins, for example, Himilan 1706 and 1605 commercially available from Mitsui-dupont Polychemical K.K. and Surlyn commercially available from E.I. dupont. A 1:1 blend of Himilan 1706 and Himilan 1605 is most preferred. In addition to the ionomer resin, the composition of which the intermediate layer is formed may further contain weight control agents, for example, inorganic fillers such as zinc oxide and barium sulfate, coloring agents such as titanium dioxide, and other additives.

The cover 3 has a radial thickness of 1 to 3 mm, preferably 1.5 to 2.5 mm. A cover more than 3 mm thick is low in repulsion whereas a cover less than 1 mm thick is low in durability such as cut resistance. Although the hardness of the cover 3 is not particularly limited, it is preferably set in a relatively soft range of 50 to 85, more preferably 60 to 85 on JIS C scale because in this range, improvements in all of repulsion (flying performance), durability and controllability are expected.

The cover 3 is generally formed of resinous materials which are conventionally used as the cover of solid golf balls, preferably those materials which are relatively soft (JIS C scale hardness 50 to 85) and highly repulsive. Examples include ionomer resins such as Himilan 1650 commercially available from Mitsui-dupont Polychemical K.K., Surlyn 8120 commercially available from E.I. dupont, and mixtures thereof, thermoplastic polyester elastomers such as Hytrel 4047 commercially available from Toray-dupont K.K., and balata resins. If necessary, inorganic fillers may be blended in these resins for coloring purposes.

EXAMPLE

Examples of the present invention are given below by way of illustration and not by way of limitation.

Examples and Comparative Examples

Using a center core, intermediate layer, and cover having the composition shown in Table 1, three-piece solid golf balls (Examples 1–6, Comparative Examples 1–3) were prepared. The center core was prepared by kneading the respective components in a roll mill and pressure molding at 155° C. for 15 minutes. The intermediate layer was formed by injection molding so as to enclose the outer surface of the center core. The cover was formed around the intermediate layer by injection molding. The three-piece solid golf balls were completed in this way. The parameters associated with the core, intermediate layer and cover are shown in Table 2.

The golf balls were evaluated for spin characteristic, flying performance, feeling, and durability by the following tests. The results are shown in Table 2.

Spin Characteristic

Using a swing robot manufactured by True Temper Co., the ball was hit by the driver at a head speed of 45 m/s (abbreviated as W1 HS45 in Table 2) and by the sand wedge at a head speed of 17.6 m/s (abbreviated as SW HS17.6 in Table 2). The ball spin (rpm) was observed using a science eye (manufactured by Bridgestone Corporation).

Feeling

Professional golfers evaluated a feeling on impact according to the following criterion.

O: good

Δ: average

×: poor

Flying Performance

In the spin and feeling tests, the flying distance the ball traveled was also measured. Total evaluation was made according to the following criterion.

O: good

Δ: average

×: poor

Durability

Using a flywheel hitting machine, the ball was repeatedly hit at a head speed of 38 m/s until the ball was broken. With the number of hits counted, the ball was rated according to the following criterion.

O: good

Δ: average

×: poor

TABLE 1

	Example						Comparative Example		
	1	2	3	4	5	6	1	2	3
Center core									
Cis-1,4-polybutadiene	100	100	100	100	100	100	100	100	100
Zinc acrylate	20	20	20	30	20	20	20	25	20
Zinc oxide	56	36	36	20	23	10	90	25	55
Antioxidant	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Dicumyl peroxide	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Intermediate layer									
Himilan 1706	50	50	50	50	50	50	50	50	50
Himilan 1605	50	50	50	50	50	50	50	50	50
Cover									
Himilan 1650	50	50	50			50	50		50
Surlyn 8120	50	50	50			50	50		50
Hytrel 4047				100				100	
Trans-isoprene rubber					90				
Natural rubber					10				

Note:
The amounts of components blended are parts by weight and their proportion is independent among the center core, intermediate layer, and cover.

TABLE 2

	Example						Comparative Example		
	1	2	3	4	5	6	1	2	3
Center core									
Outer diameter, mm	31.52	35.28	35.28	35.28	35.29	36.40	27.68	35.24	31.52
Hardness, JIS C	66	66	66	79	66	66	66	73	66
Specific gravity	1.36	1.24	1.24	1.19	1.16	1.07	1.56	1.19	1.35
Intermediate layer									
Thickness, mm	3.4	1.7	2.2	2.2	1.7	2.0	5.7	1.8	1.6
Hardness, JIS C	91	91	91	91	91	91	91	82	91
Specific gravity	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.97	0.95
Outer diameter, mm	38.35	38.73	39.65	39.66	38.73	40.40	39.00	38.91	34.56
Cover									
Thickness, mm	2.2	2.0	1.5	1.5	2.0	1.8	1.8	1.9	4.0
Specific gravity	0.97	0.97	0.97	1.10	1.13	0.97	0.97	1.10	0.97
Hardness, JIS C	82	82	82	61	78	82	82	61	82
Ball									
Outer diameter, mm	42.68	42.67	42.67	42.70	42.70	44.00	42.65	42.63	42.65
Weight, g	45.50	45.45	45.50	45.55	45.53	45.60	45.50	45.55	45.50
Performance									
Spin (rpm) W1 HS45	3300	3020	3030	3920	3600	3030	35	3600	3250
SW HS17.6	3900	4000	4300	6390	5800	4100	4100	4050	3500
Feeling	Δ	O	O	Δ	O	O	X	O	O
Flying performance	O	O	O	O	Δ	O	X	X	X
Durability	O	O	O	O	O	O	O	O	O

As is evident from Table 2, the three-piece solid golf balls of the present invention have a good balance of properties in that the center core and cover can be made soft to ensure a pleasant feeling and controllability (spin) without deteriorating flying performance and durability.

There has been described a three-piece solid golf ball which includes a core, intermediate layer and cover having controlled size, hardness and specific gravity so that the ball has a good total balance of properties in that a relatively soft center core and cover are used to ensure a pleasant feeling and controllability at no sacrifice of flying performance and durability.

Japanese Patent Application No. 5-193065 is incorporated herein by reference.

Although one preferred embodiment have been described, many modifications and variations may be made thereto in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

We claim:

1. A three-piece solid golf ball comprising;

a center core, an intermediate layer, and a cover enclosing the core through the intermediate layer,

said center core having a diameter of at least 29 mm and a specific gravity of less than 1.4,

said intermediate layer having a thickness of at least 1 mm, a specific gravity of less than 1.2, and a hardness of at least 85 on JIS C scale, the specific gravity of said intermediate layer being lower than the specific gravity of said center core, and

said cover having a thickness of 1 to 3 mm and being softer than said intermediate layer.

2. The golf ball of claim 1 wherein said intermediate layer is formed of a high repulsion ionomer resin base composition.

3. The golf ball of claim 1 wherein said center core has a hardness of 45 to 80 on JIS C scale and said cover has a hardness of 50 to 85 on JIS C scale.

4. The golf ball of claim 1 wherein said center core is comprised of a polybutadiene base rubber composition.

5. The golf ball of claim 1 wherein the diameter of said center core is in the range of 29–37 mm.

6. The golf ball of claim 1 wherein a difference in the specific gravity between the center core and the intermediate layer is in the range of 0.1 to 0.5.

7. The golf ball of claim 1 wherein the specific gravity of said intermediate layer is in the range of 0.9 to 1.0.

8. The golf ball of claim 1 wherein the hardness of said intermediate layer is in the range of 85–100 on JIS C.

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